BABU

water distribution system operation and maintenance

Environment
Environnement
Ontario
Jim Bradley, Minister/ministre

BABU

OPERATION AND MAINTENANCE OF WATER DISTRIBUTION SYSTEMS

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Training and Certification Section
Personnel Services Branch
Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

Other manuals relating to the water and wastewater treatment processes published by the Training and Certification Section, Ministry of the Environment, include:

Basic Sewage Treatment Operation

Basic Water Treatment Operation

Surface Water Treatment Workshop

Activated Sludge Process Workshop

Preventive Maintenance Workshop

Pump Operation Workshop

Basic Gas Chlorination Workshop

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INTRODUCTION

The Water Distribution System Operation and Maintenance manual has been prepared as a home study and reference manual and as the text for the related workshop. The principal objective of the Workshop is to upgrade the knowledge and skills of water distribution system staff. The lesson objectives are clearly indicated at the beginning of each topic and tell the trainee what he must know or do having covered the topic. Upon completion of the Workshop, the trainee is expected to attain a minimum level of competence of 70% for the course.

This is a working course in which each person is expected to take an active part in subject discussions. It includes considerable hands-on instruction, in order to provide as much practical training as possible.

The Training and Certification Section wishes to acknowledge the assistance and contributions of the following in the preparation of the manual:

MUNICIPAL ENGINEERS ASSOCIATION (MEA)
MEA/MOE Course Sub-Committee
which participated in the
development of the workshop.

Various manufacturers, suppliers
and consultants.

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L I S T O F A P P E N D I C E S

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WATER DISTRIBUTION

SYSTEM OPERATIONS

TOPIC: 1

Water Sources and Treatment

OBJECTIVES:

Provided for Information only

SOURCES AND TREATMENT

SOURCES OF WATER

Water can be considered one of the most important natural resources of this country. Although we hear a great deal about the millions of lakes and streams in Canada, very little mention is made about waters hidden beneath the land's surface. This hidden wealth is called *ground water* and actually makes up the vast bulk of our fresh water supplies.

It is estimated that moisture laden air moving over land masses from oceans drops about 30 inches of precipitation in the form of rain and snow on North America each year. About 60-80% of this is returned to the atmosphere by direct evaporation as it falls, by evaporation from the land surface, by evaporation from bodies of water, by evaporation from vegetation and by transpiration.

A small amount, some 20 percent, moves downward to become ground water in the saturated zone. This water under the influence of gravity moves at rates from 5'/day to 5'/year.

It usually appears at the surface as a spring or discharges into a stream lake or ocean (e.g. streams still flowing after periods of sparse rainfall).

Only during periods of intense rainfall do appreciable quantities of precipitation run off directly to streams without passage through the ground. Ground water and surface water are not separate and distinct but closely interrelated. See Figure 1-1 THE HYDROLOGIC CYCLE.

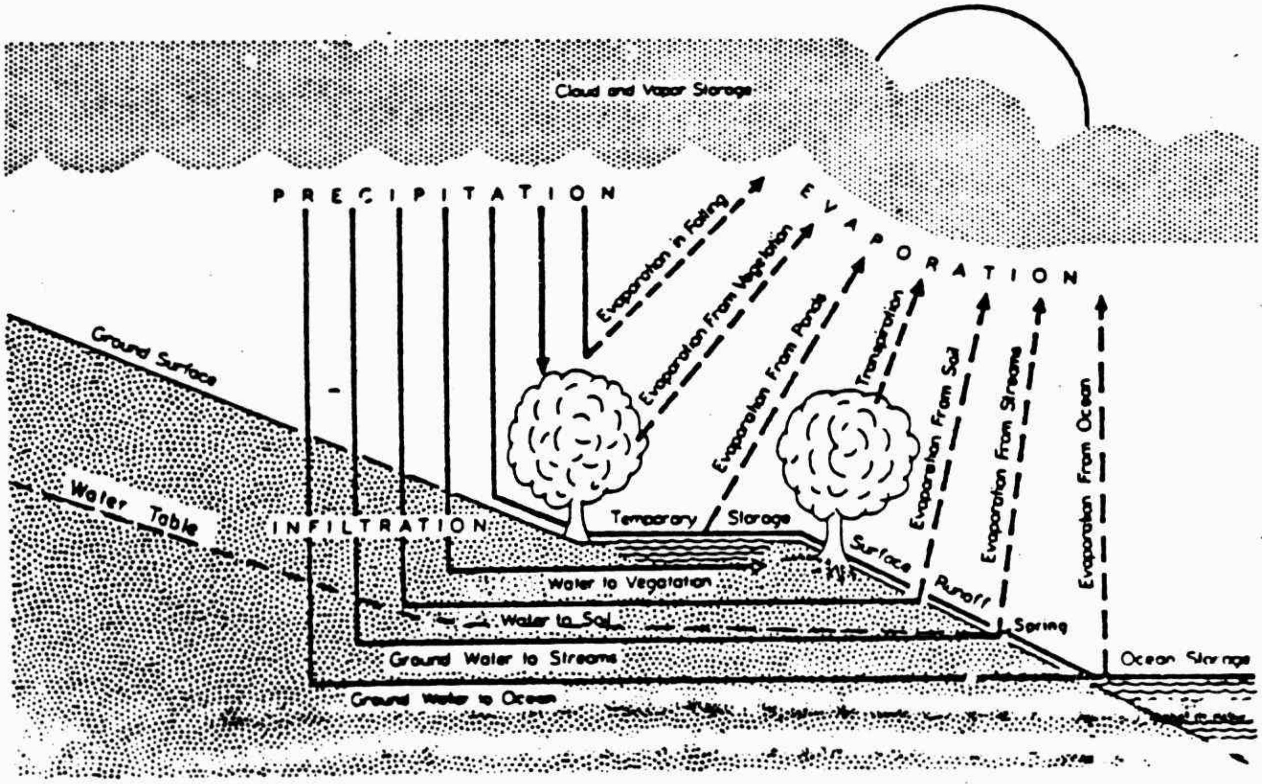


Figure 1-1 The Hydrologic Cycle

GROUNDWATER

Although ground water makes up less than 1/3 of water used in Ontario, most estimates place the ground water supply in excess of 80%, and all surface supplies, including the Great Lakes, at less than 20%.

Advantages offered by ground sources are:-

1. It can be developed on-site
2. Quality and temperature less variable
3. It can be extracted at a sufficient rate;
4. No storage or only limited storage required
5. Essentially a protected supply
6. Economical
7. More widespread than surface sources.

On the other hand there are some disadvantages.

These include:-

1. Usually quite hard and may contain other minerals in solution. Water moving through the atmosphere comes in contact with many soluble materials which are contained in solution. Ground water may contain hydrogen sulphide, salt iron sulphate flourides etc.

2. Pollution is more difficult to correct. Spills of hazardous material or careless disposal of wastes can irreparably affect ground water quality.

3. Sometimes difficult to locate are aquifer which will yield an adequate quantity of ground water. The pre-cambrian rocks of northern Ontario are generally poor aquifers. High capacity wells are located in sand and gravel deposits.

   The limestones and dolomites of southern Ontario vary greatly in ability and quality of water produced.

   Shale formations yield only small quantities of water but the water is much softer than that from limestone. Salty water is frequently encountered at shallow penetration of shale formations.

Iron & Manganese Removal

The constituents which probably cause most problems with ground water are iron and manganese. The two in combination are much more difficult to remove than iron alone. Iron and manganese removal may be integrated with other treatment, but often it is the only treatment with or without disinfection in the system.

Softening

Calcium and magnesium are the hardness-causing elements, present as bicarbonates, sulphates or chlorides. Table 1-1 shows the common hardness scale. There are two processes for removal of calcium and magnesium, lime-soda-ash treatment and base exchange or zeolite treatment.

TABLE 1-1

Common Hardness Scale

Hardness Level	mg/l $CaCO_3$
Soft Water	0 - 60 mg/l
Med. to moderately	61 - 120 mg/l
Hard Water	121 - 180 mg/l
Very hard water	180 mg/l

1 grain per Imp. Gal. = 14.3 mg/l

Taste and Odour

Activated carbon or charcoal is widely used for removing tastes, odours and colour from water. This is a physical action called adsorption.

TREATMENT OF GROUND WATER

A ground water source which is well protected and maintains satisfactory bacteriological and chemical quality may not need any treatment. Chlorination facilities are required for emergency disinfection etc.

Figure 1-2 illustrates the most common systemg used in Ontario to process ground water. In many instances, Figure 1-2(1), no treatment is required, the water being pumped from the well to the reservoir and then to the distribution system.

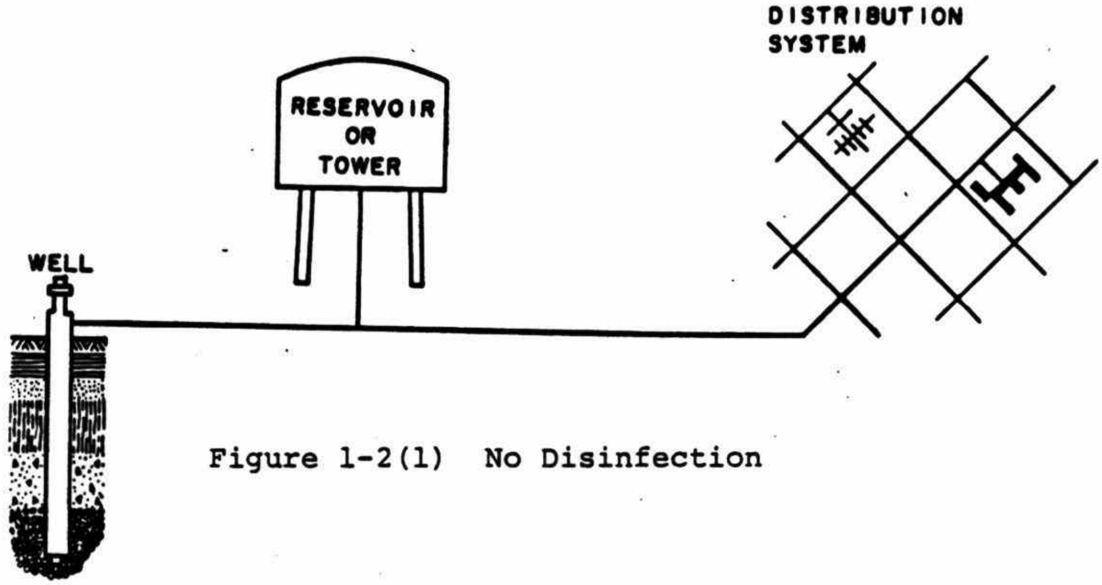


Figure 1-2(1) No Disinfection

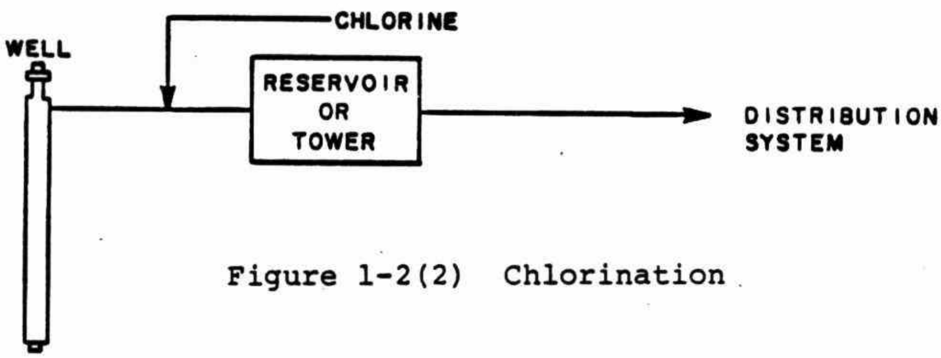


Figure 1-2(2) Chlorination

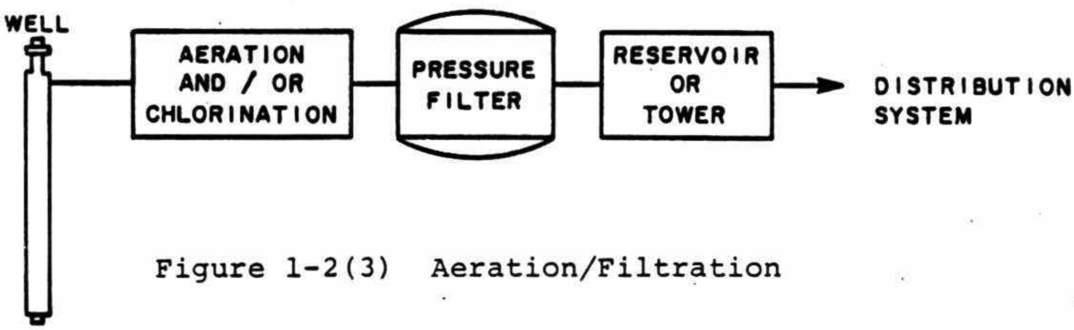


Figure 1-2(3) Aeration/Filtration

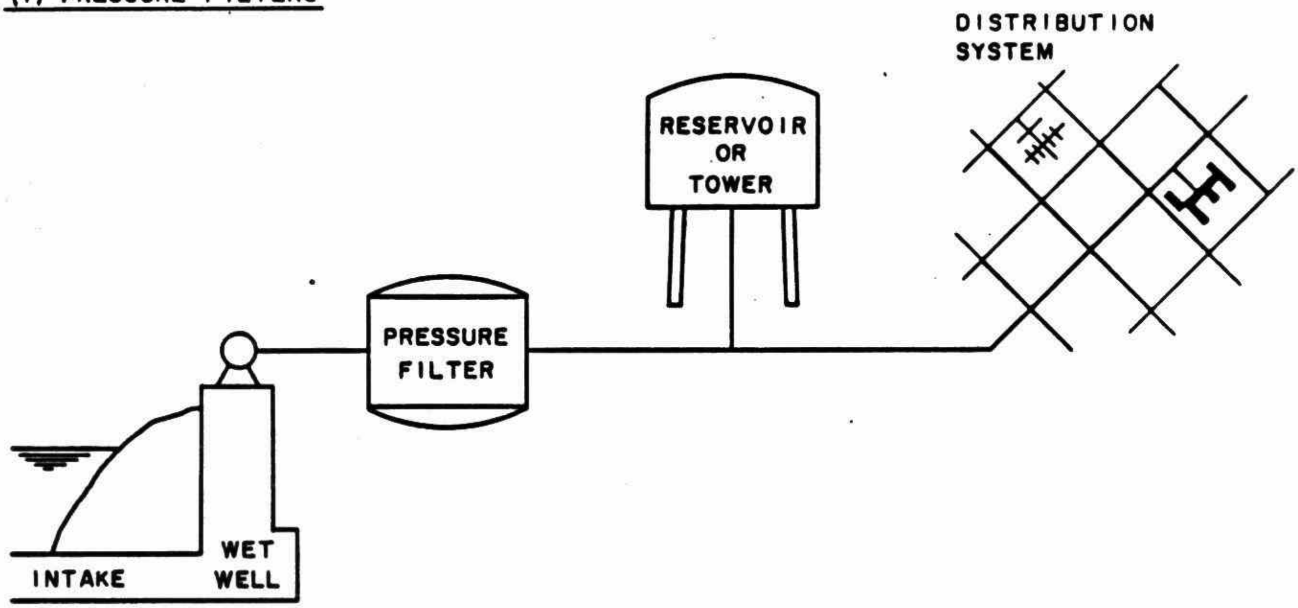
Figure 1-2 Ground Water Treatment

Figure 1-3

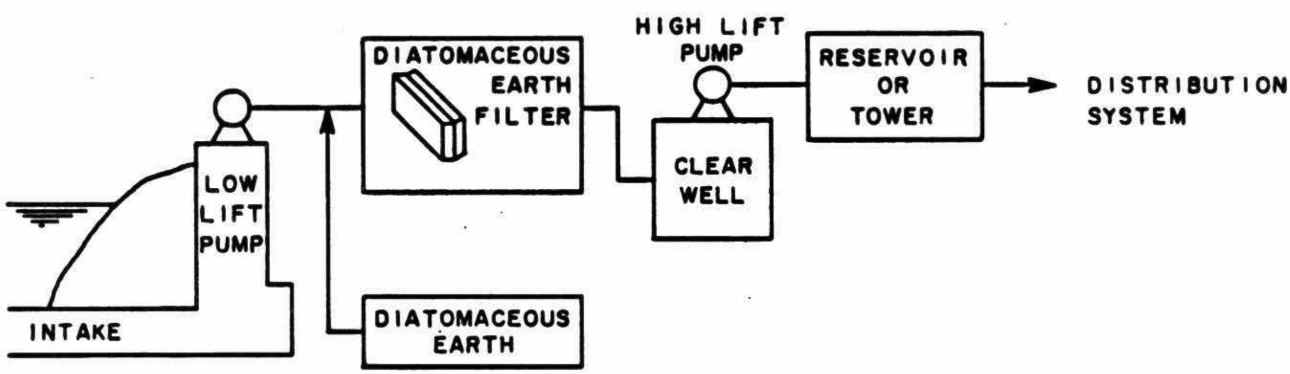
SURFACE WATER TREATMENT SYSTEMS COMMON IN ONTARIO

LOW RAW WATER TURBIDITY

(1) PRESSURE FILTERS



(2) DIATOMACEOUS EARTH FILTRATION



(3) DIRECT FILTRATION

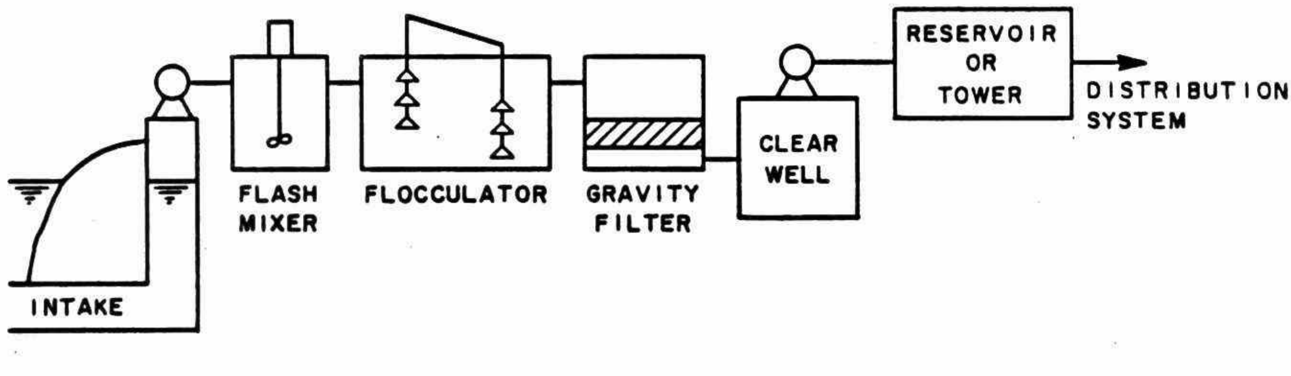


Figure 1-2(2) depicts a system where chlorination is required because of adverse bacteriological tests or for distribution system control. When double pumping is used, the chlorine injection point should be to the suction of the high lift pump, or the storage basin. When an agent is used for iron control, chlorine should be fed to protect the distribution system.

Figure 1-2(3) illustrates a system employing aeration and/or chlorination to deal with hydrogen sulphide and disinfection and filtration to remove turbidity.

There are other methods of treating ground water such as deionzation, desalination and reverse osmosis, etc. which are used principally by industries and in some cases, by individual homeowners but they are not used in municipal applications in Ontario.

SURFACE WATER TREATMENT

General

The characteristics of the raw surface water determines the complexity of the treatment process. Figures 1-3 and 1-4 are schematic drawings of the surface water treatment systems in Ontario. Treatment varies from pressure filtration Figure 1-3(1) to the use of flash mixers, flocculation, sedimentation and filtration when chemicals are added for taste, turbidity and colour removal.

Disinfectants

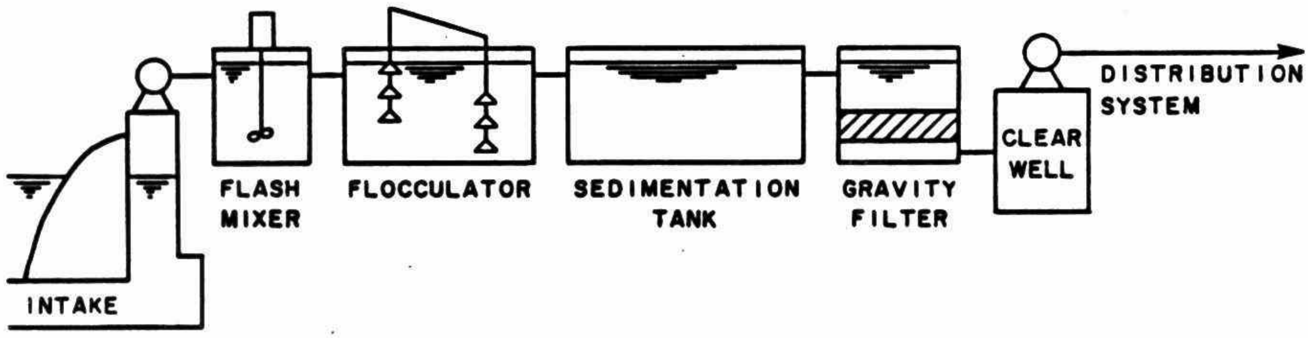
The principal disinfectant is chlorine but others such as ozone and chlorine dioxide may be used in conjunction with chlorine. The water to be disinfected must be low in turbidity and have no other constituents which interfere with the process. Turbid waters, as well as being difficult to disinfect adequately, contribute to a build-up of material in water mains which tend to cause taste and odour problems as well as reducing the carrying capacity of the mains.

Figure 1-4

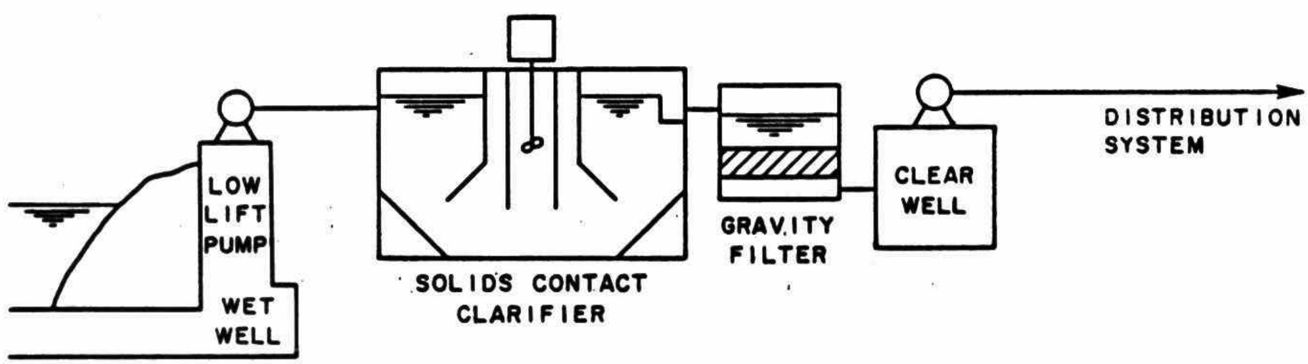
SURFACE WATER TREATMENT SYSTEMS COMMON IN ONTARIO

HIGH RAW WATER TURBIDITY

(1) SEDIMENTATION



(2) CLARIFICATION



SUBJECT:

WATER DISTRIBUTION SYSTEM OPERATIONS

TOPIC: 2

Treated Water Quality

OBJECTIVES:

The trainee will be able to:-

1. Recall the physical characteristics of water and recommended objectives in treated water.

2. Recall the minimum number of samples required for bacteriological analysis and their frequency.

3. Recall the sampling requirement for
   a. physical analysis
   b. chemical analysis.

4. Recall the method and related considerations for
   a. physical/chemical sampling
   b. microbiological sampling.

TREATED WATER QUALITY

INTRODUCTION

According to the drinking water objectives of the Ministry of the Environment, water supplies must be free from amounts of chemical substances and micro-organisms that would constitute a health hazard; additionally, the water should be aesthetically as attractive as possible, being free from turbidity, colour and disagreeable tastes and odours.

In order to determine if a water in a distribution system meets the objectives of the Ministry, it is periodically tested. However, no testing programme can take the place of a complete knowledge of conditions in the distribution system. When a sanitary inspection indicates that a distributed water is being contaminated, the water should be considered suspect even if the results of testing fail to reveal that contamination.

DRINKING WATER OBJECTIVES

The **objectives established** for a water supply are for three main characteristics; physical, chemical and microbiological.

Physical

Drinking water should contain no impurity which would cause offence to the sense of sight, taste or smell. The parameters which are tested and their recommended objectives are shown in Table 2.1.

TABLE 2.1

OBJECTIVES FOR THE PHYSICAL CHARACTERISTICS OF DRINKING WATER

Parameter	Limit
Turbidity	1 Ftu
Colour	5 units
Threshold odour number	3

The threshold odour number is measured by a special test, where a panel of individuals determine the level of taste or smell in a sample of water, and characterize it. Samples for physical analysis should be collected one or more times a week from representative points in the distribution system.

Chemical

Drinking water shall not contain impurities in concentrations that may be hazardous to the health of the consumer. The substances, such as alum and chlorine used in the treatment of the water, should not remain in the water in concentrations greater than that required for good practice, and the water should not be corrosive to the system. Table 2.2 shows a list of chemical substances and the concentrations which should not be exceeded for drinking water. Above these levels, it is generally accepted that some health effect may occur, or some problem for the consumer will result. For example, an iron level above 0.3 ppm, will result in the staining of bathroom fixtures. However, waters with more than the maximum will be accepted, if there is no alternative source and no serious public health hazard would result.

TABLE 2.2

CHEMICAL SUBSTANCES IN DRINKING WATER

Substance	Concentration mg/l
Alkyl benzene sulfonate (ABS)	0.5
Arsenic (As)	0.01
Chloride (Cl)	250
Copper (Cu)	1.0
Carbon chloroform extract (CCE)	0.2
Cyanide (CN)	0.01
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (N)	10.0
Phenols	0.001
Sulphate (SO_4)	250
Total dissolved solids	500
Zinc (Zn)	5.0
Total organic carbon	5.0
Organic nitrogen	0.15
Methane (ground water only)	50 cu ft/100,000 gals

The presence of substances in Table 2.3 in excess of the concentrations listed, would result in the rejection of the supply, because serious public health hazard would result.

TABLE 2.3

CHEMICAL SUBSTANCES IN DRINKING WATER

Substance	Concentration mg/l
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Cr_6 +)	0.05
Cyanide (Cn)	0.2
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

Fluoride levels constitute a special situation. When fluoride is naturally present in drinking water the concentration should not average more than 1.2 mg/l; the supply should be rejected if fluoride exceeds 2.4 mg/l.

When fluoride is added to the water, the concentration recommended is 1 mg/l, with a permissable operating range of 0.8 mg/l to 1.2 mg/l.

Chemical samples are only normally required to be taken semi-annually from a distribution system, except under unusual circumstances where contamination of the distribution system with undesirable compounds is suspected.

Microbiological

Water used for domestic purposes should be free from disease-producing micro-organisms. It is reasonably certain that such organisms are absent if no pollution-indicating bacteria are found in 100 ml samples. Therefore, there should be no fecal coliforms present in the sample, and less than 5 total coliforms. Should these limits be exceeded, special samples should be immediately collected from the affected and adjacent locations, and the operating authority should investigate the reason for their presence. If the special samples are also in violation of the limits, remedial action is taken. Bacteriological sampling is carried out much more frequently than chemical, and is designed to enable proper supervision of the bacteriological quality of the water in the entire distribution system. The minimum number of samples to be collected from a distribution system is determined from Table 2.4.

TABLE 2.4

MINIMUM NUMBER OF WATER SAMPLES FOR BACTERIOLOGICAL ANALYSIS

Population served	Minimum number of samples/month	Minimum Frequency
Up to 100,000	8 + 1 per thousand of population	Weekly
Over 100,000	100 + 1 per thousand of population	Daily

The samples should not necessarily be taken from the same location each time, in order that as full a picture as possible of the entire distribution system is obtained.

GENERAL SAMPLING PROCEDURES

The samples that are submitted for these tests must be taken correctly. It cannot be emphasized enough that the sampler plays a key role in ensuring that the data obtained, accurately reflect the field situation being assessed. In general, the sampler's aim must be to collect a representative sample from a known position (location) and transfer it to the laboratory with a minimal change in composition. The method of sampling differs according to whether physical/chemical or microbiological testing is being carried out. Fire hydrants are not recommended as sampling points, because as a result of their design, they are subject to extraneous contamination. However, should it be necessary to sample from a hydrant, the valve should be opened fully and the water allowed to flush through the hydrant for several minutes, following which the samples may be taken using the prescribed techniques.

CHEMICAL/PHYSICAL SAMPLING

The samples must be representative of the water in the main and all possible sources of contamination (sampling devices, motor exhausts) should be eliminated. For some analysis a preservative is recommended, which fixes the concentration of the particular substances for which analysis is required. However, the sample should still be sent to the laboratory with the least possible delay.

Sampling Containers

For routine chemical testing in the distribution system, the types of container and the volume of sample required are shown in Table 2.5. Special studies may specify a certain container type or preservative, and this

should be determined prior to the collection of the samples.

Method of Sampling

All aerators and hoses should be removed from the sample tap. The tap should be allowed to run fully open for two minutes to ensure that the sample obtained is from the main, and not from the consumers piping. For sample bottles not already containing a preservative, rinsing both the bottle and the cap with sample water several times is recommended. This tends to equilibrate the sample with the container and minimize container effects eg. Leaching. Bottles containing preservative should not be rinsed.

MICROBIOLOGICAL

It is the responsibility of the sampler to use aseptic techniques when handling the sterile bottles used for microbiological sample collection; if the technique described is not followed closely, the sample will become contaminated and the results will be meaningless.

Sample Containers

For all samples of chlorinated distribution system water, pre-sterilized 6 oz. bottles containing sodium thiosulphate (red labels) must be used. The sodium thiosulphate is used to neutralize the disinfecting properties of chlorine to preserve the microbial population at the time of sampling. Samples of unchlorinated water, or samples for "nuisance" organisms should be collected in pre-sterilized 6 oz. regular (blue label) bottles. Special sampling bulbs are available for depth samples e.g. in reservoirs. Normally, one bottle or bulb provides sufficient sample volume for microbiological analysis.

Method of Sampling

Only those bottles with intact seals should be

TABLE 2.5

CONTAINER TYPES FOR COMMON PARAMETER GROUPS

Group	Routine Parameters	Possible Additional Parameters	Bottle Type & Volume Required	Preservation Technique	Comment
Routine Drinking Water	Hardness, Alkalinity Chloride, Iron, pH, Conductivity	Colour Turbidity Fluoride	1 x 32 oz, 1 x 20 oz. or 1 litre glass or plastic bottle	Refrigerate	
Taste & Odour Group	Hardness, Alkalinity Chloride, Nitrate Iron, pH, Conductivity, Kjeldahl, Nitrogen TOC		1 x 32 oz, 1 x 20 oz or 1 x litre glass bottle	Refrigerate	Phenol requires special preservative bottle
Trace Metal Group	Cadmium, Copper, Iron, Lead, Zinc		1 x 32 oz plastic bottle	20 drops concentrated HNO_3	

used. If possible, samples should be taken early in the week and should be packed in ice during spring, summer and fall and prevented from freezing during the winter. All aerators, screens and hoses should be removed before sampling and the tap should be allowed to run full flow for two minutes; this cleans residual contamination from the tap and ensures that the sample is from the main; water pressure may then be reduced to take the sample. Only the outer surface of the cap should be handled; if the inner surface of the cap or bottle lip are accidentally touched, the sample must be considered contaminated and should be discarded. Sample bottles should not be rinsed, as this would increase the chance of contamination and/or remove the preservative. The recommended procedure is to hold the cap in the finger tips (do not put it down) until the sample has been taken.

SAMPLE SUBMISSION

All samples should be submitted to the laboratory as soon as possible. Bacteriological samples are preferably analyzed within six hours and delivery time should not exceed twenty four hours; samples reaching the laboratory after seventy two hours will not be analyzed. Some chemical samples can be kept indefinetly, but most analyses should be done with as little delay as possible.

Sample Bottle Labelling

Sample bottles must be clearly labelled in waterproof pen, with the following information:-

1. A sender's sample number; the use of a simple field numbering system is to be encouraged.
2. Other identification, normally the sample source or type (eg. distribution water, 1 1st. Avenue).
3. The presence of any chemical preservative added.
4. When appropriate, indicate the single specific analysis required for that particular sample bottle (eg. for chlorinated organics).

Submission Forms (Appendix A).

Much of the effort expended in taking samples may be wasted because of carelessness in completing the submission forms. Forms should be filled out legibly in waterproof ink and should include the following information:-

1. The analysis required, including the occasions when a parameter group (eg. routine drinking - Table 2) is requested. Samples requesting "for chemical analysis" will not be accepted. If there is some doubt concerning the request, a brief description of the problem or the reason for the sample will enable analytical personnel to select the appropriate test.
2. The sender's number (corresponding to that on the sample bottles) and the other sample identification on the bottle.
3. The sampler's name, and the name, address and phone number of the person to whom the results are to be reported. This much information can be pre-entered on every form at headquarters, prior to the sampling trip. This avoids the possible non-entry on a form in the field. The program or study involved and the region or head office branch may also be pre-entered where appropriate.
4. The sampling date.
5. As much relevant information as possible should be included: too much information is preferable to too little.

Shipping Procedures

CN and CP Express provide the most reliable service for the shipment of environmental water samples. It is important to keep a record of all contract numbers, and to affix this

number to all shipments, as this is the only method of tracing a lost shipment. Samples may be shipped to the Central Laboratories or to a Regional Laboratory, whichever is appropriate.

Tracing Samples

All samples received by the laboratory are assigned numerical codes according to the sample types and all original submission sheets are retained in the files. To answer any inquiries, the following information is required;-

1. Municipality or township from which the samples came.
2. Name of person receiving the report.
3. Program or study.
4. Sampling date and estimated day of arrival at the laboratory.
5. Sample identification or laboratory numbers if known.
6. The type of sample (eg. drinking water, sewage etc.)

Much of this material has been extracted from "Drinking Water Objectives" and "A guide to the Collection and Submission of Samples for Laboratory Analysis". The former publication is available from Information Services Branch, MOE, 135 St. Clair Avenue West, Toronto, M4V 1P5, and the latter from the 'Water Quality Section, Laboratory Services Branch'.

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MINISTRY OF THE ENVIRO ENT
LABORATORY BRANCH
P.O. BOX No. 213
REXDALE, ONTARIO

MINISTRY OF THE ENVIRONMENT
LABORATORIES

XPRESS ADDRESS:
RESOURCES ROAD
HIGHWAY 401 & ISLINGTON AVE.
TORONTO, ONTARIO

Municipality: TOWNSHIP OF ANYPLACE
Source: DISTRIBUTION SYSTEM Region: S. W. CENTRAL
Program: CROSS CONNECTION CONTROL
Date sampled: AUGUST 21/75 by: K B C
Date analysed: Date reported:

Report to: A. J. SMITH
Address: 12 HEADQUARTERS RD
ANYWHERE
416 123-4567

C	
Bi	
Ba	✓

LAB. NUMBER	SENDER'S NUMBER	SAMPLING POINT LOCATIONS AND TIME / NATURE OF SAMPLE, DANGEROUS CONSTITUENTS, PRESERVATIVES USED, COMPOSITING DATA, ETC.	✓CHECK BELOW IF CHLORINE PRESENT
	A-1	DISTRIBUTION WATER AT # 1 - 1st AVE. (9 A.M.) THIOSULPHATE. SUSPECTED CROSS CONNECT	✓

LAB. NUMBER											

INSTRUCTIONS

SAMPLING DIRECTIONS

This form should accompany all samples, with copies included for each laboratory (chemical, bacteriological and biological) to which samples are submitted. Samples for each laboratory should be taken in separate, individually labelled bottles. Suitable bottles are available, on request, from the laboratory Stores. Phone: 248-3051. No charge is made for routine analyses. The sender shall bear all shipping costs.

ALL SAMPLES ARE PERISHABLE. Please submit promptly, as early in the week as possible. Keep samples cool, preferably chilled, and away from light. Avoid freezing. Samples may be delivered to the laboratory anytime; at night, or on weekends and holidays, they will be refrigerated.

BACTERIAL STERILE BOTTLES (6 OZ. OR MORE) MUST BE USED. TO ENSURE RELIABLE RESULTS, SAMPLES SHOULD ARRIVE AT THE LABORATORY WITHIN 24 HOURS OF SAMPLING OR BE REFRIGERATED IF DELAY IS UNAVOIDABLE.

For other than routine examinations, please enquire beforehand. Phone: 248-3008. DO NOT OPEN THE BOTTLE until all other sampling preparations have been made, then discard the cellophane dam. Samples from taps must be taken only after aerators, screens and hoses, etc., have been removed, and THEN only after the water has been running for two minutes. Samples from open waters must be taken by tying a clean copper wire to the bottle's neck before removing the cap, and then lowering it below the water's surface. Collect samples directly in the sterile bottles provided and NOT BY MEANS OF A DIPPER. While bottle is being filled, hold cap in hand – DO NOT LAY IT DOWN. Do not touch its inner surfaces or the mouth of the bottle with hands or any other object. Always leave an air space in the bottle unless advised otherwise.

CHEMICAL Our standard 1 ltr. bottle contains sufficient sample for routine tests only. (Since sludge samples develop gas, leave bottle half-empty). Additional non-routine tests require more sample (2 bottles) and special sampling and handling techniques. Please enquire beforehand. Phone: 248-3512.

BIOLOGICAL Any specimens for identification should be refrigerated or preserved in 5% formaldehyde and submitted as soon as possible. Where special biological analyses are desired, sampling procedures are best arranged with the biological staff beforehand. Phone: 248-3011.

SPECIAL SAMPLES

Please refer to the "Guide to the collection and submission of samples for laboratory analysis" for information regarding types of sample containers, preservation techniques and sample volumes. Sampling enquiries should be directed to the appropriate region, section, unit and/or individual listed.

WATER These include samples taken from sources of supply, treatment and distribution systems and waters used for drinking, domestic or industrial purposes.

- ☑ BACTERIAL Coliform
- ☐ CHEMICAL – Hardness, Alkalinity Iron, Chlorides, pH
- ☐ BIOLOGICAL EXAMINATION

SEWAGE AND STREAM Include samples taken from waste discharges, waste collection and treatment systems. To detect pollution, the probable source shoulde be sampled, together with the receiving water, prior to and following entry of the pollution. Describe the type of pollution, and its ingredients, below:

- ☐ BACTERIAL Coliform
- ☐ CHEMICAL – Biochemical Oxygen Demand, Suspended Solids or Turbidity
- ☐ BIOLOGICAL EXAMINATION

SPECIAL ANALYSES

For other than routine determinations, preliminary discussion with laboratory staff facilities, and often is essential for an appropriate and reliable analysis. Please refer to "Guide to the collection and submission of samples for laboratory analysis". Enter below a brief description of the problem which has necessitated the submission of samples, designating the materials sought or suspected of being present.

Describe Problem: ____________________

SUBJECT:

WATER DISTRIBUTION
SYSTEM OPERATIONS

TOPIC: 3

Water Quality Problems

OBJECTIVES:

The trainee will be able to:-

1. Recall the sources of water quality problems in a distribution system.
2. Recall the types of problems related to the sources of these problems.

WATER QUALITY PROBLEMS

GENERAL

Problems in a water distribution system derive from the raw water supply and from effects occurring with the distribution system. If water source quality is good, with or without treatment, (e.g. bacteria free, non-aggressive, aesthetically acceptable, chemically satisfactory (no iron or manganese) there should normally be no problems of drinking quality in a distribution system.

Treatment can be wasted if no consideration is given to the effect of the finished water leaving the treatment process into the system. For example, if iron is removed in the treatment process and the water remains aggressive, iron can be picked-up from the distribution system.

In general you cannot resolve problems in the distribution system caused by an inadequate treatment process or by inadequate delivery into the system.

SOURCES OF PROBLEMS

The problems which this topic will discuss are those resulting from characteristics of the following qualities of the water:

1. Chemical
2. Bacteriological & biological
3. Aesthetic - colour, taste, odour, turbidity, temperature
4. Physical - pressure and flow, system maintenance & operation
5. Reliability of supply
6. Chlorine residual.

The types of problems referred to above may be further identified under the following sub-titles:

1. <u>Chemical Quality</u>

   a. Aggressiveness
   b. Hardness
   c. Mineral content
   d. Deposits
   e. Organic content

2. <u>Bacteriological Quality</u>

   a. Bacteria counts occurring in distribution system
   b. Presence of Nuisance and Presumptive pathogenic organisms in system.

3. <u>Aesthetics</u>

   a. Colour pick up from system
   b. <u>Turbidity</u>
      (1) as a result of aggression
      (2) picked up suspended matter from reverse flow or high velocity

   c. <u>Taste & Odour</u>
      (1) introduced through raw water supply as:
         (a) chlorophenols
         (b) decaying organic material
         (c) other means
      (2) formed in system from pipe, fittings and other materials.

   d. <u>Temperature</u> - Introduction from raw water supply. Affects palatability.

4. <u>Physical</u>

   a. <u>Pressure</u> - Unreasonably high or low

b. Flow - High flow or high demand, water shortage

c. System maintenance effects

   (1) cross-connections, main breaks

   (2) pressure relief & reducing valves, altitude valves, vacuum breakers, air relief, surge arrestors

   (3) physical water quality

d. System operation

   (1) pump application, use of storage

   (2) pump back systems, water shortage

5. Reliability of Supply

   a. Emergency measures - System Storage

   b. Pressure with plant or power failure

   c. Icing of intakes

   d. Pollution of source

6. Disinfection (Chlorination)

   a. Residual profile in system piping & storage

   b. Effectiveness

   c. Type of residual - free, combined or both

   d. Organo - halides

   e. Re-chlorination

   f. Pipe repair and new pipe and facility disinfection

   g. Disposal of heavy chlorinated water.

CHEMICAL QUALITY

Aggressiveness

Many water sources are aggressive in character and quite often are supplied to the distribution system in the

same aggressive condition. These waters are usually characterized by a relatively soft water with low pH and low alkalinity. Such waters will react with metals such as iron, lead and zinc as well as cement in the system.

The effect can produce coloured and turbid water particularly in dead ends and sluggish flow areas and extract lead from lead services or breakdown galvanized services where they exist.

Some aggressive waters contain iron and manganese. Treatment to remove these components is somewhat fruitless unless the water is treated to a non-aggressive condition.

Hardness

Hard water has more effect in the household, on commerce and industry than the distribution system itself. Examples are kettles, humidifiers, steam plants, water heaters, laundries, etc. Excessive hardness can require local treatment for specific uses and users.

Mineral Content

Excessive mineral content can be discovered by taste of water quite often and can also have marked physiological effect. Quality standards suggest the upper limit of mineral content. The mineral level if too high must be removed at the source or the source abandoned. One very evident area is in the household furnace humidifier.

Deposits

Deposits originate in the distribution system from:

1. Residual turbidity or organic or biological

carry over such as algae after treatment or in the water supply.

2. Chemical actions continuing in the distribution system are for example:

   a. After-flocculation from alum
   b. Manganese dioxide production from excessive usage of potassium permanganate
   c. Precipitation of iron or manganese as a result of chlorination.

3. Carry over of inert content of post treatment chemicals such as lime. Such material can deposit in sluggish flow areas or dead ends and be picked-up during periods of heavy flow demand creating consumer complaints.

4. Organic deposits from algae passing into the distribution system from the raw water source can decompose in the system and create tastes and odours particularly where the system chlorine residual is virtually non-existent.

BACTERIOLOGICAL QUALITY

Bacteria can normally only be introduced into the system from the water source or from outside contamination sources such as:

1. Cross connections

2. System appurtenances such as air vents, vacuum breakers, surge arrestors, open reservoirs, reservoirs, pipe materials, etc.

3. Repaired mains or new mains.

Turbid waters allowed into the system may contain encapsulated bacteria which are difficult to expose to disinfection. An aggressive water can create nodules and tubercles in the piping which can effectively harbour bacteria. Occasionally colonies slough off into the water stream and a high count may be experienced even in the presence of a good chlorine residual. A non-aggressive water with a relatively high pH appears to reduce the bacterial activity.

Bacterial contamination can disappear as quickly as it appears or can be persistent in the system. Should persistent bacterial counts occur in a system, a high level effort must be made to trace the source and to identify the type of bacteria. A bacteria profile taken throughout the system may show a concentration pattern indicative of the contaminant source. The supply is normally the first suspect area with contamination from system repair works or operating facilities coming next.

Sampling techniques are very important in arriving at meaningful results. The object of the sample must always be kept in mind. Sampling under standard methods is concerned with the water quality at the sample point and therefore flaming of the sample point is not allowed. If the sample point however is for the purpose of transmitting a sample of water from the main to the sample bottle, the sample point should be free of bacteria and should be flamed for security.

Most bacteriological testing is carried out by the area Department of Health who would direct appropriate action to be taken by the utility to safeguard public health.

AESTHETIC QUALITY

The aesthetic qualities of water in the distribution system such as colour, turbidity, taste and odour,

temperature, etc. can be attributed directly to the water quality entering the system. Colour and turbidity can be controlled by the treatment process and taste and odour to a lesser extent. Temperature is dependent to a great extent on the source of supply.

Taste and odour can also be attributed generally to the raw water source and attendant treatment, if any. If no odour causing material appears in the raw water source and the water is non-aggressive then it is almost impossible for taste and odour to occur in the distribution system under normal operating circumstances. Taste and odour generally occur because of contamination of the raw water source, by materials such as phenols, algae, industrial wastes and from a carry over of organic material from the source into the system with resultant decomposition within the system regardless of chlorine residual.

Taste and odour is one of the most elusive problems in water quality because in a large number of cases it occurs only spasmodically and a captive sample can rarely be obtained of the problem water. Since most taste and odour problems become apparemt after a consumer complaint, by this time it is probably too late to obtain a representative sample. Since in most cases the source of taste and odour is from the supply, it is suggested that a composite sample of water be kept on hand for each day, each sample being retained for 2 or 3 days for threshold odour tests and for treatment response.

One commonly hears comments that taste and odour treatment "does not work". It is quite possible, however, in most cases that the treatment dosage, assuming the treatment diagnosis is correct, is insufficient for the level of problem experienced.

The captive sample can also be used as a comparison between a sample from the distribution system and one from the source.

Turbidity - System Flow Reversal

This phenomenon usually occurs in systems where feed-back or reversal flow occurs from outlying storage reservoirs with pumpback facilities or even under gravity flow conditions where the direction of flow is reversed for a shorter period of time than the main flow pattern exists. Normal finished water turbidity, which has deposited in the distribution system for many years, forms ripples somewhat like the sand ripples on a beach. When the flow is reversed the peaks of these ripples are removed and carried in suspension in the water which results in periodic consumer complaints. The only solution to this problem is flushing of the system with the reverse pump-back system in operation hopefully with critical consumers not connected to the system until this has been carried out.

PHYSICAL QUALITY

General

It is reasonable to suggest that the physical characteristics of a water supply system, such as pressure, flow, etc. may constitute the definition of quality. Inadequate pressure or flow represents a poor quality of supply to the consumers. It is important that the system operators have a fundamental background training in the system hydraulics.

Most problems arise during peak demand periods when the system may be taxed to its utmost, and a breakdown in delivery performance occurs due to a basic lack of understanding of the system operation. For example, with an open pressure system using elevated storage, the hydraulic system profiles hinge at all times around the water level in the storage tank. If a certain pumping rate is required from the main plant or pumping station, the station pressure must (by laws of physics) be sufficient to provide that hydraulic flow gradient to the storage level.

Hydraulic Network

A good analysis of the hydraulic system network greatly assists in understanding where areas of low pressure can regularly be expected to occur. With this knowledge remedial measures can readily be taken.

Pump Performance

Pump performance curves must be understood in order to control output rates from a pumping station at all times to satisfy the distribution system requirements in terms of flow and pressure.

System Appurtenances

Water hammer or sub-atmospheric pressure problems can occur in a system during periods of transient flow such as rapidly increased or reduced pumping or flow rates due to rapid valve opening or closure, rapid pump shut-down, power failure or a broken main.

The system can be protected under these circumstances by having sufficient pipe strength to withstand the maximum surge pressure variations anticipated or by having protective devices such as surge arresting valves, air valves and vacuum breakers to limit the pressure variations to the normal working strength of the piping system. These devices if improperly installed can be sources of contamination for the distribution system. Air valves, vacuum breakers and surge arrestors should have free openings above any possible outside water level or above any possible flood level so that foreign or contaminated water is not drawn into the system under low pressure conditions.

Cross Connections

System cross connections have been talked about for years but still occur and sometimes in areas outside the

normal working jurisdiction of the water utility. A good public relations programme, particularly with industry can help in overcoming some of these problems.

Facilities which have two sources of supply, such as, a private well water system for non-potable use and another supply from the municipal system, are always a potential source of danger from cross connection. See Topic 14.

Main Breaks

A broken watermain is a very common occurrence. A not so common occurrence is the possible attendant breakage of a sewer due to violent disruption within the roadway. With a large hole in the road and disruption of the sewer, it is possible when the water is shut off for a mixture of sewage and water and other debris to enter into the watermain. This was more evident in World War II during bombing than possibly occurs in every-day operation under present day conditions. Thorough cleaning, flushing and chlorination of the watermain with a thorough bacteriological quality survey is vital prior to putting the watermain back into service. Lumps of dirt are major culprits in harbouring bacteria which would not be destroyed even at the high chlorination levels of 50 mg/L. Small mains cannot be inspected visually and therefore very thorough flushing is vitally desirable.

RELIABILITY OF SUPPLY

Using the broadest definition of water quality which includes an adequate supply, such quality of service is severely tested under emergency conditions.

Such emergency conditions can cover a vast range of problems such as:

1. Contaminated water source (oil spillage,

bacteriological contamination or physical contamination).

2. Icing up of intake or supply source.

3. Prolonged power failure.

4. Major system rupture.

5. System overload due to unanticipated system demand.

In these terms, water quality can be preserved by adequate preparation and understanding in how to cope with such problems. If necessary emergency facilities should be available.

In some cases a curtailment of supply is necessary regardless of the preparation and awareness of problems. An adequate public relations programme, underway before such a happening occurs, can lessen the impact and number of consumer complaints.

CHLORINE RESIDUAL

A chlorine residual entering the distribution system is very important to ensure some protection to the system water quality. Problems of taste and odour can occur because of an excessive residual or no residual.

Residual Profile

If a sample of chlorinated finished water is taken, it is interesting to measure and record the chlorine residual existing at various time intervals.

A typical residual profile for three applied chlorine dosages of 2.5, 4.5 and 6.5 mg/L is shown on figures 3-1. It is readily evident for the lowest dosage

that the remaining residual at the end of one hour is only 20 percent of that applied. If the residual leaving the plant is increased to maintain a target value at the end of a designated period of time, it may be a cause for taste and odour complaint from consumers at the beginning of the system. For example if it is desirable to have a residual of 0.2 mg/L at the end of a 10 hour period, the applied chlorine dosage for this case would have been about 3.2 mg/L. Under these circumstances if the first consumer received water within 45 minutes from the time of chlorine application, the residual would be about 1.2 mg/L and it is quite likely that a complaint would be registered.

These residual curves are based on time/residual measurements but may not accurately indicate conditions in the distribution system because of chlorine demand from foreign substances resident in the system.

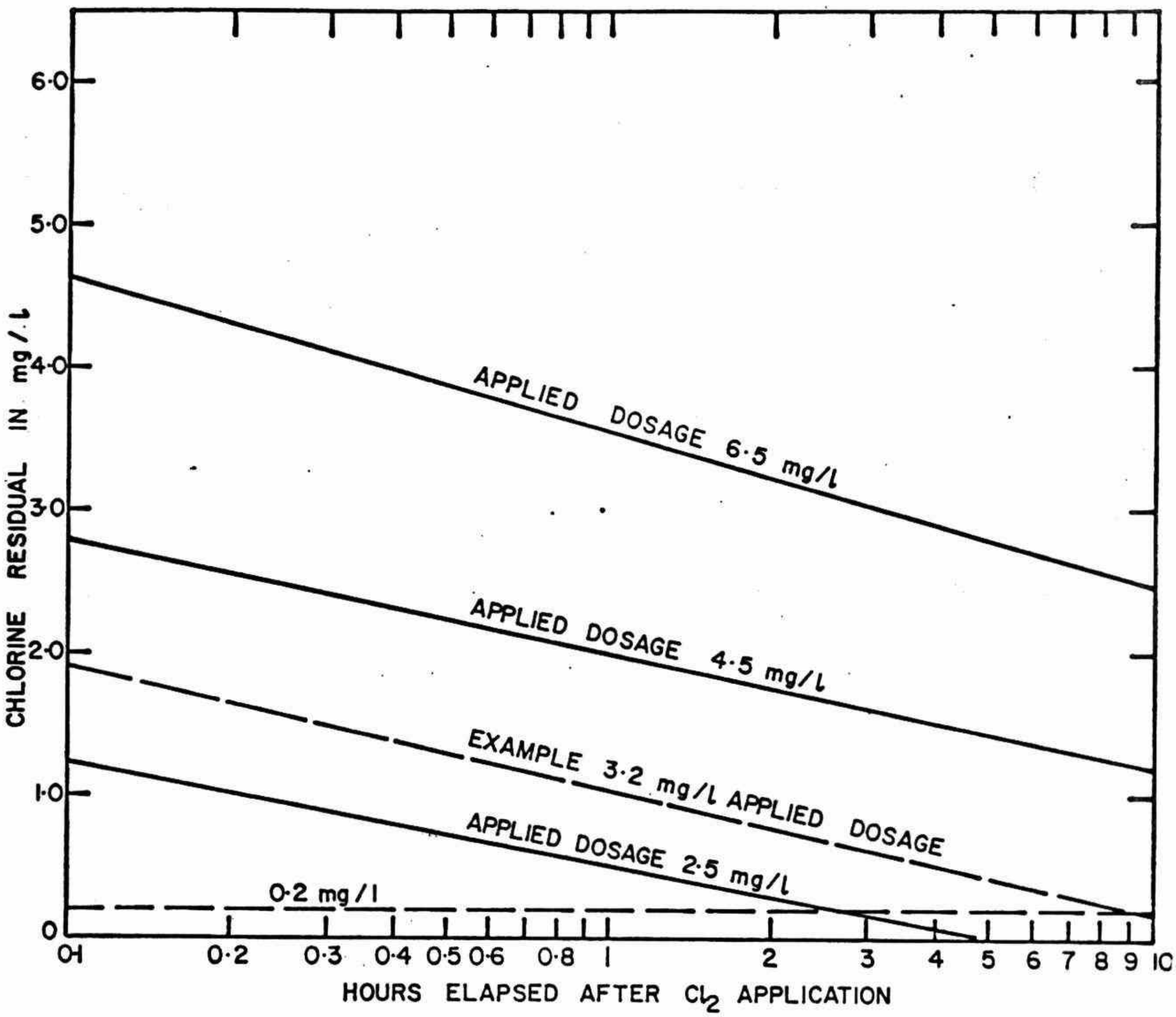
A profile of chlorine residual taken throughout the distribution system compared with the plant profile is a valuable tool in assessing the distrbution system operation.

Type of Residual

Should the chlorine residual be in the combined of free form? Combined chlorine has a considerably lower disinfecting power than free chlorine. On the other hand, a water carrying a free chlorine residual into the distribution system quite often cannot maintain a measurable free chlorine residual throughout the system. The choice should be at least partly based on the bacteriological and chemical quality of water and the type of treatment used, if any.

FIGURE 3-1

TYPICAL CHLORINE RESIDUAL / TIME PROFILE



Organo halides (tri-halomethanes)

Public health considerations must take first place in the list of priorities in dealing with a water system. In relation to chlorination, there is a concern that tri-halomethanes formed by the interaction between chlorine and certain organic compounds in the water could be detrimental to human health. One of the most commonly mentioned compounds is chloroform.

It can be shown that where the necessary organic compounds exist in the water source, the amount of tri-halomethane (e.g. chloroform), formed is somewhat dependent upon the dosage rate of chlorine applied to the water. In this situation, therefore, care must be taken in balancing the chlorine requirements for disinfection with the desirable limit with respect to the formation of tri-halomethanes.

No Chlorination Use

There are still some municipalities which do not practice disinfection of the water supplies. This occurs predominantly with well water supplies. In theory, a water entirely free of pathogenic bacteria or viruses entering a distribution system should remain pure.

There are however, many pitfalls which can obviously occur even in the best operated systems. A disinfectant residual will provide insurance against some untoward happening in the system.

Pipe Repairs

A broken water main or appurtenance is an obvious avenue for a pollutant to enter the system particularly undesirable bacteria or viruses. Great care must be taken to adequately clean and disinfect the repaired section of

the system and to ensure the adequacy of the disinfection by taking samples and subjecting them to bacteriological examination.

Under no circumstances should a repaired system be returned to service until a clean bill of health is obtained or until a satisfactory and adequate disinfection programme has been carried out.

Disposal of Heavily Chlorinated Water

Recommendations for disinfecting systems, prior to placing into service, call for chlorine dosages of 50 mg/L. Quite often, after a satisfactory disinfecting period, the remaining residual is quite high, much too high to be acceptable into the system. The discharge of this water can often present a problem and care should be taken to ensure that no environmental damage occurs as a result of such a discharge. For example discharge into a natural drainage system terminating in a pond or lake can cause a massive fish skill.

SUBJECT:

WATER DISTRIBUTION SYSTEM OPERATIONS

TOPIC: 4

Basic Hydraulics

OBJECTIVES:

The trainee will be able to:-

1. Define the standard terms and units used in hydraulics.
2. Using a diagram show the relationship between various pressure terms.
3. Recall the factors which affect friction losses in pipe.
4. Define various terms which apply to the pumping of liquids.
5. Using a diagram, relate the following terms to Total Static Head:
   a. Static Friction Head or lift;
   b. Static Discharge Head.
6. Understand, and demonstrate the application of, a system head curve.

BASIC HYDRAULICS

INTRODUCTION

Hydraulics is the study of water or liquid in motion or under pressure and the methods of conducting or raising it. The subject here will be confined to that part of hydraulics which deals with water supply systems.

STANDARD TERMS AND UNITS

Flow Rate and Velocities

The rate of flow is the measurement of water or liquid that flows through a conduit or pipe during a certain time period. This is usually measured in gallons per minute (gpm) or gallons per day (gpd).

Velocity

Velocity is the average speed at which water moves through a certain cross-section or past a certain point. This is usually measured in miles per hour (mph) or feet per second (fps). The relationship between these terms is stated by the mathematical formula, $Q = AV$ where Q is the flow rate, V is the velocity and A is the cross-sectional area at right angles to the direction of flow.

Pressure and Head

When water flows through a system under a force, that force measured per unit of area is termed pressure. Pressure is usually stated in pounds per square inch (psi). Static pressure refers to the force exerted when water is at rest and not flowing. Pressure exerted by flowing water is known as dynamic pressure.

It is often more convenient to express pressure in terms of a height of a column of fluid of constant unit weight. Therefore, the pressure at the bottom of a water column depends directly, and only, on the height of the column. When pressure is expressed in this way it is commonly referred to as pressure head. The head may be expressed by the formula h = p/w where 'h' is the head in feet of water or some fluid, 'p' is the pressure in square feet and 'w' is the unit weight of the fluid in pounds per cubic foot (pcf). For water the unit weight is usually assumed as 62.4 pcf. Feet of head for water may be converted to psi by multiplying by the factor of 0.433. Sometimes it is convenient to express head in terms of height of another fluid such as inches of mercury. Heads are expressed in either gauge pressure or absolute pressure. Absolute pressure is equal to the gauge pressure plus the barometric pressure. The barometric pressure is the level of atmospheric pressure above a perfect vacuum and varies with altitude. The atmospheric pressure at sea level is 14.696 psi. Gauge pressure is measured above atmospheric pressure. That is, practically all pressure gauges register zero when open to the atmosphere. Vacuum refers to a pressure below the atmospheric level. In a vacuum a gauge pressure would register a negative value. Therefore, the absolute pressure would be below atmospheric pressure. Figure 4.1 graphically illustrates the relationship between these pressures.

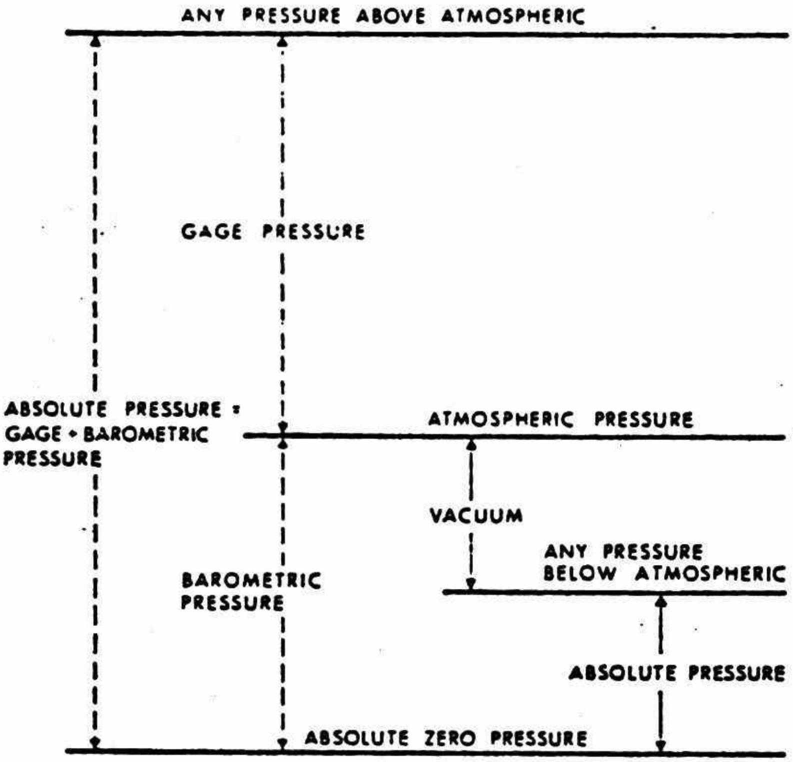


Figure 4.1 Relationship Among Pressure Terms

Gauge pressures are almost always used in problems dealing with liquids.

Approximate equivalent forms for expressing atmospheric pressure of 14.7 psi at sea level are as follows:

29.9 inches of mercury, 33.9 ft. of water.

Elevations and Geodetic Datum

Vertical positions used for water systems are often given by surveys done from a standard level known as a standard datum. This is also referred to as a geodetic datum and mean or average sea level is often used. The vertical heights above the standard datum are called elevations. A marked point of known elevation is called a bench mark, usually abbreviated to B.M.

Hydraulic Gradient

The head at any point in a water system refers to the height to which the water would rise if it were not contained. That is, if freely vented stand pipes were placed along a pipeline, the water would rise to a certain head in these stand pipes. The imaginary line joining the elevations of these heads is known as the hydraulic grade line. The slope or steepness of this imaginary line is called the hydraulic gradient. This slope determines the quantity or rate of flow in a line. The slope or hydraulic gradient is frequently used to represent the head at a particular position. The hydraulic gradient is the loss due to friction or head loss in feet for a particular pipe, plus the difference in elevation of the two ends of the pipe divided by the horizontal distance between the ends. An abnormal drop in the gradient shows unusual flow. Thus large leaks of heavy draughts of water from a system may be detected readily by checking the hydraulic gradient. The dashed line of Figure 4.2 is a typical example of the hydraulic gradient of a pipeline of different pipe sizes with a certain gradient for each pipe size. The hydraulic grade line shown only occurs when the hydrant is flowing. When there is no flow the hydraulic gradient is at the same slope as the water in the reservoir.

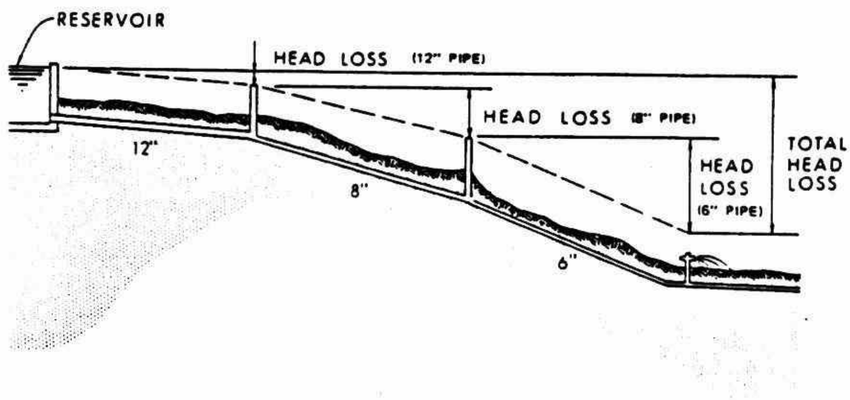


Figure 4.2 Hydraulic Gradient and Effects of Pipe Size

FRICTION LOSS IN PIPES

Friction occurs whenever there is flow through pipes. Friction causes a loss of head or drop of the hydraulic gradient. Friction losses in a pipeline depend on the velocity or rate of flow, the length and size or diameter of a pipe, and the apparent roughness of the pipe surface contacting the water. For a particular rate of flow in a pipe, the larger the pipe diameter or the smoother the interior pipe surface, the less the head loss due to friction will be. The resistance which a pipe offers to the flow of water or the degree of pipe roughness is commonly denoted by a coefficient known as a 'C' factor. 'C' factors range from 90 to 140 for most pipe materials. The table shown below illustrates some values of 'C'.

Description of the Pipe	Values of C
Extremely smooth and straight	140
Cast iron:	
New	130
5 years old	120
10 years old	107-113
20 years old	90-100
30 years old	75-90
Concrete or cement lined	120-140
Welded steel, as for cast-iron pipe, 5 years older	
Riveted steel, as for cast-iron pipe, 10 years older	
Wood stave	120

Table 4.1 'C' Values

The larger values of 'C' of cast iron pipe apply to 24-inch diameter and larger, the smaller values apply to 4-inch diameter pipe.

Head or friction losses for 100-foot lengths of pipe of varying sizes for a 'C' factor of 100 are shown in Appendix A. For example, the head loss that would occur through 100 feet of 2-inch pipe for a flow of 100 gpm, is found by following the "USgpm" column to 100, then moving across the "Loss in Ft." column for 2-inch pipe. The head loss is read as 35.8 feet. Multiplying this figure by 0.433 yields a 15.5 psi loss. Imperial gallons may be converted to U.S. gallons by multiplying by 1.2. For longer lengths of pipe the friction loss is found by multiplying the values from the table by the number of 100-foot pipe lengths through which the water flows. That is, multiply by 23.4 for 2340 feet of pipe. The value may be adjusted for a 'C' factor other than 100 by multiplying the flow rate of 100/C and using the new flow rate in the table. Thus for the previous example, for a 'C' factor of 125 instead of 100, the adjusted flow rate would have been 100 gpm x 100/125 or 80 gpm. Using 80 gpm in the table yields a loss of 23.2 feet for the same conditions as previously. Thus, the smoother piper loses less head for each 100 feet of length.

In addition to friction losses due to flow through straight pipe, losses occur through fittings, bends and orifices. Special constants and charts exist to tabulate these losses. The 'C' factor is a coefficient used in the Hazen-Williams Formula for determining flow and is limited to the condition of water flowing in a closed conduit under pressure.

THE HAZEN-WILLIAMS FORMULA

Various pipe flow formulas are used to obtain head losses in relation to velocity in pipes. However, in water systems, the formula most commonly used in hydraulic calculations is the Hazen-Williams Formula. It is written in the form:

$$V = 1.318\ C\ R^{0.63}\ S^{0.54}$$

in which

- 'V' is the velocity in the pipe in feet per second
- 'C' is the coefficient of roughness of the pipe
- 'R' is the 'Hydraulic Radius' of the pipe in feet and is the ratio of water area to the wetted perimeter of pipe. For a circular pipe flowing full this becomes the diameter divided by 4
- 'S' is the slope of the hydraulic gradient or head loss in feet per length of pipe in feet.

The Hazen-Williams formula is difficult to use mathematically. Therefore, there are special hydraulic slide rules and tables and curves available for use to apply the formula. In common use is the line chart or nomogram shown in Figure 4.3. It is based upon a 'C' factor of 100 and will apply to pipes in use for 15 to 20 years with a normal water. This nomograph may be used as an alternative to Appendix A.

As an example, a pipe 8 inches in diameter and 2,000 feet long carries 500 gpm. A straight edge is set on the 8-inch mark on the diameter line and the 500 mark on the quantity line. Where the straight edge cuts the other lines, it is read that the loss of head is 7.8 feet per 1000 feet of length and the velocity is 3.1 feet per second. The total loss of head in the line will be 2 x 7.8 = 15.6 feet. In the same way, if other values are known any other corresponding value may be found. When determining pipe sizes, the next commercial pipe available above the theoretical size is chosen. For head loss for different 'C' factors, multiply the loss obtained by the nomograph by a 'K' value as follows:

'C'	40	60	80	90	100	110	120	130	140
'K'	5.46	2.58	1.51	1.22	1.00	0.838	0.713	0.615	0.536

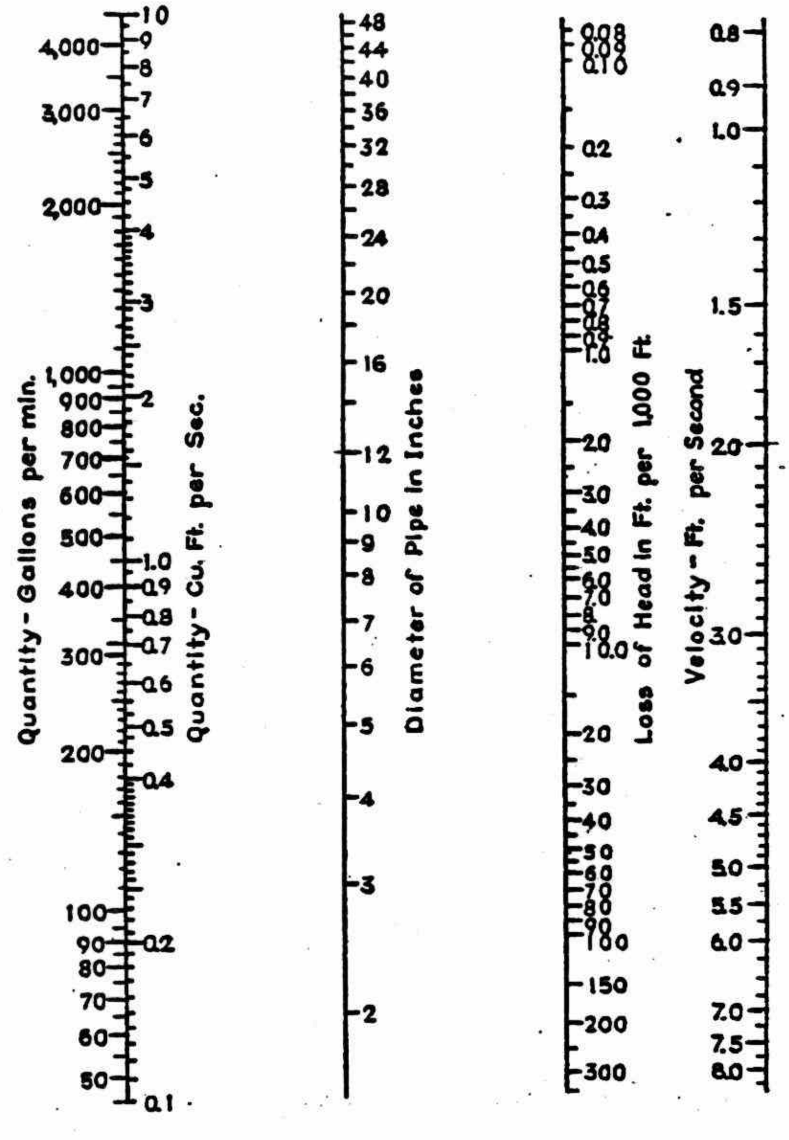


Figure 4.3 Flow in Old Cast Iron Pipes (Hazen-Williams Formula, C = 100)

PUMP TERMS

Every pump has a capacity rating referring to the amount of water or liquid which it can handle in a definite period of time. This is usually stated in gallons per minute (gpm) or million gallons per day (mgd) at a certain head. The head against which a pump operates must be accurately determined in order to arrive at a pump with the correct characteristics to handle the job required. The total head against which a pump operates comprises several components that include suction and discharge conditions as well as friction head in pipes and fittings when the pump is operating at full capacity. Velocity head and entrance and exit losses must also be taken into consideration.

Static suction lift is the vertical distance from the liquid supply level to the pump centreline, the pump being above the supply level.

Static discharge head is the vertical distance from the pump centreline to the point of free delivery of the liquid. Care should be used to determine the point of free delivery for the static discharge head.

Total static head is the vertical distance between the supply level and the discharge level of the liquid being handled, that is, the distance between the supply level and the point of highest lift.

When both the suction and discharge are under atmospheric pressure, the total static head is merely a difference in elevation. A pump may operate against a varying static discharge head such as when the discharge pipe enters the bottom of an elevated tank where the water level in the tank changes. For total head, however, the elevation used should be the highest water level in the tank. These distances under varied conditions are shown in Fig. 4.4.

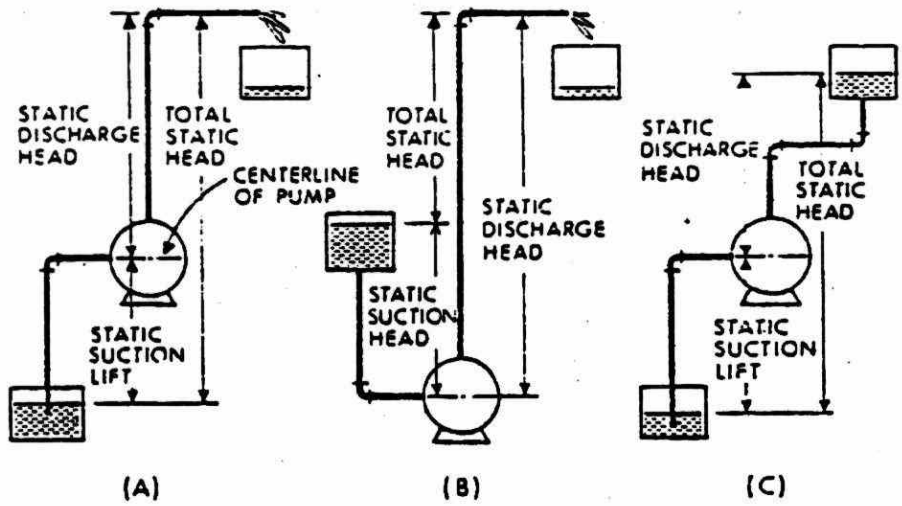


Figure 4.4 Head Terms Used in Pumping

Friction head is that needed to overcome the resistance of pipe, valves, and fittings in the system. It exists on both the suction and discharge sides of the pump.

Entrance and exit losses are head losses that occur at the entrance and exit of the piping and at abrupt changes in piping sizes.

Suction lift exists when the suction measured at the suction nozzle of the pump, corrected to the centreline of the pump, is below atmospheric pressure. It is the sum of static suction lift and friction head in the suction line, plus velocity head plus entrance and velocity losses.

Suction head is the static suction head minus the suction friction head and entrance losses.

Discharge head consists of the static discharge

head, plus the head necessary to overcome friction in the discharge line, plus the velocity head, plus the exit and velocity losses.

Total head is the sum of the suction lift and the discharge head, or, where there is a suction head, the difference between the discharge and suction heads.

Velocity head of water moving at a certain velocity is the equivalent head of water through which it would have to fall to produce the same velocity.

Pump efficiency is the measure of a pump's ability to convert motor brake horsepower to water horsepower. This is normally expressed as a percentage and changes as operating conditions change.

In order to select the correct pump for a certain condition, pump performance characteristics curves are drawn up and supplied by manufacturers. These show how the pump capacity changes with changes in discharge pressure or suction conditions. Appendix B discusses the principles and application of a system head curve.

FRICTION LOSS OF WATER PER 100 FEET LENGTH OF PIPE (INSIDE DIAMETER)

Based on Williams & Hazen Formula Using Constant 100

Sizes of Standard Pipe in Inches

½" Pipe Vel. per Sec.	½" Pipe Loss in Feet	3/4" Pipe Vel. per Sec.	3/4" Pipe Loss in Feet	1" Pipe Vel. per Sec.	1" Pipe Loss in Feet	1¼" Pipe Vel. per Sec.	1¼" Pipe Loss in Feet	1½" Pipe Vel. per Sec.	1½" Pipe Loss in Feet	2" Pipe Vel. per Sec.	2" Pipe Loss in Feet	2½" Pipe Vel. per Sec.	2½" Pipe Loss in Feet	3" Pipe Vel. per Sec.	3" Pipe Loss in Feet	4" Pipe Vel. per Sec.	4" Pipe Loss in Feet	5" Pipe Vel. per Sec.	5" Pipe Loss in Feet	6" Pipe Vel. per Sec.	6" Pipe Loss in Feet	U.S. Gals. Per min.
2.10	7.4	1.20	1.9																			2
4.21	27.0	2.41	7.0	1.49	2.14	.86	.57	.63	.26													4
6.31	57.0	3.61	14.7	2.23	4.55	1.29	1.20	.94	.56	.61	.20											6
8.42	98.0	4.81	25.0	2.98	7.8	1.72	2.03	1.26	.95	.82	.33	.52	.11									8
10.52	147.0	6.02	38.0	3.72	11.7	2.14	3.05	1.57	1.43	1.02	.50	.65	.17	.45	.07							10
		7.22	53.0	4.46	16.4	2.57	4.3	1.89	2.01	1.23	.79	.78	.23	.54	.10							12
		9.02	80.0	5.60	25.0	3.21	6.5	2.36	3.00	1.53	1.08	.98	.36	.68	.15							15
		10.84	108.2	6.69	35.0	3.86	9.1	2.83	4.24	1.84	1.49	1.18	.50	.82	.21							18
		12.03	136.0	7.44	42.0	4.29	11.1	3.15	5.20	2.04	1.82	1.31	.61	.91	.25	.51	.06					20
				9.30	64.0	5.36	16.6	3.89	7.30	2.55	2.73	1.63	.92	1.13	.38	.64	.09					25
				11.15	89.0	6.43	23.0	4.72	11.0	3.06	3.84	1.96	1.29	1.36	.54	.77	.13	.49	.04			30
				13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.10	2.29	1.72	1.59	.71	.89	.17	.57	.06			35
				14.88	152.0	8.58	40.0	6.30	18.8	4.08	6.6	2.61	2.20	1.82	.91	1.02	.22	.65	.08			40
						9.65	50.0	7.08	23.2	4.60	8.2	2.94	2.80	2.04	1.15	1.15	.28	.73	.09			45
						10.72	60.0	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38	1.28	.34	.82	.11	.57	.04	50
						11.78	72.0	8.66	34.0	5.62	11.8	3.59	4.01	2.45	1.58	1.41	.41	.90	.14	.62	.05	55
						12.87	85.0	9.44	39.6	6.13	13.9	3.92	4.65	2.72	1.92	1.53	.47	.98	.16	.68	.06	60
						13.92	99.7	10.23	45.9	6.64	16.1	4.24	5.4	2.89	2.16	1.66	.53	1.06	.19	.74	.076	65
						15.01	113.0	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57	1.79	.63	1.14	.21	.79	.08	70
						16.06	129.0	11.80	60.0	7.66	20.9	4.91	7.1	3.33	3.00	1.91	.73	1.22	.24	.85	.10	75
						17.16	145.0	12.59	68.0	8.17	23.7	5.23	7.9	3.63	3.28	2.04	.81	1.31	.27	.91	.11	80
						18.21	163.8	13.38	75.0	8.66	26.6	5.56	8.1	3.78	3.54	2.17	.91	1.39	.31	.96	.12	85
						19.30	180.0	14.71	84.0	9.19	29.4	5.86	9.8	4.09	4.06	2.30	1.00	1.47	.34	1.02	.14	90
								14.95	93.0	9.70	32.6	6.21	10.8	4.22	4.33	2.42	1.12	1.55	.38	1.08	.15	95
8" PIPE								15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96	2.55	1.22	1.63	.41	1.13	.17	100
								17.31	122.0	11.23	42.9	7.18	14.5	5.00	6.0	2.81	1.46	1.79	.49	1.25	.21	110
								18.89	143.0	12.25	50.3	7.84	16.8	5.45	7.0	3.06	1.17	1.96	.58	1.36	.24	120
								20.46	166.0	13.28	58.0	8.48	18.7	5.91	8.1	3.31	1.97	2.12	.67	1.47	.27	130
.90	.08							22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2	3.57	2.28	2.29	.76	1.59	.32	140
.96	.09									15.32	76.0	9.81	25.5	6.82	10.5	3.82	2.62	2.45	.88	1.70	.36	150
1.02	.10									16.34	86.0	10.44	29.0	7.26	11.8	4.08	2.91	2.61	.98	1.82	.40	160
1.08	.11	10" PIPE								17.36	96.0	11.11	34.1	7.71	13.3	4.33	3.26	2.77	1.09	1.92	.45	170
1.15	.13									18.38	107.0	11.76	35.7	8.17	14.0	4.60	3.61	2.94	1.22	2.04	.50	180
1.21	.14									19.40	118.0	12.42	39.6	8.63	15.5	4.84	4.01	3.10	1.35	2.16	.55	190
1.28	.15									20.42	129.0	13.07	43.1	9.08	17.8	5.11	4.4	3.27	1.48	2.27	.62	200
1.40	.18	.90	.06							22.47	154.0	14.38	52.0	9.99	21.3	5.62	5.2	3.59	1.77	2.50	.73	220

1.53	.22	.98	.07							24.51	162.0	15.69	61.0	10.89	25.1	6.13	6.2	3.92	2.04	2.72	.87	240
1.66	.25	1.06	.08							26.55	211.0	16.99	70.0	11.80	29.1	6.64	7.2	4.25	2.41	2.95	1.00	260
1.79	.28	1.15	.09									18.30	81.0	12.71	33.4	7.15	8.2	4.58	2.77	3.18	1.14	280
1.91	.32	1.22	.11									19.61	92.0	13.62	38.0	7.66	9.3	4.90	3.14	3.40	1.32	300
2.05	.37	1.31	.12	12" PIPE								20.92	103.0	14.52	42.8	8.17	10.5	5.23	3.54	3.66	1.47	320
2.18	.41	1.39	.14									22.22	116.0	15.43	47.9	8.68	11.7	5.54	3.97	3.86	1.62	340
2.30	.45	1.47	.15			14" PIPE						23.53	128.0	16.32	53.0	9.19	13.1	5.87	4.41	4.08	1.83	360
2.43	.50	1.55	.17	1.08	.069							24.84	142.0	17.25	59.0	9.69	14.0	6.19	4.86	4.31	2.00	380
2.60	.54	1.63	.19	1.16	.075							26.14	156.0	18.16	65.0	10.21	16.0	6.54	5.4	4.55	2.20	400
2.92	.68	1.84	.23	1.28	.95									20.40	78.0	11.49	19.9	7.35	6.7	5.11	2.74	450
3.19	.82	2.04	.28	1.42	.113	1.04	.06							22.70	98.0	12.77	24.0	8.17	8.1	5.68	2.90	500
3.52	.97	2.24	.33	1.56	.135	1.15	.07							24.96	117.0	14.04	28.7	8.99	9.6	6.25	3.96	550
3.84	1.14	2.45	.39	1.70	.159	1.25	.08							27.23	137.0	15.32	33.7	9.80	11.3	6.81	4.65	600
4.16	1.34	2.65	.45	1.84	.19	1.37	.09									16.59	39.0	10.62	13.2	7.38	5.40	650
4.46	1.54	2.86	.52	1.99	.22	1.46	.10									17.87	44.9	11.44	15.1	7.95	6.21	700
4.80	1.74	3.06	.59	2.13	.24	1.58	.11	16" PIPE								19.15	51.0	12.26	17.2	8.50	7.12	750
5.10	1.90	3.26	.66	2.27	.27	1.67	.13									20.42	57.0	13.07	19.4	9.08	7.96	800
5.48	2.20	3.47	.75	2.41	.31	1.79	.14	1.36	.08							21.70	64.0	13.89	21.7	9.65	8.95	850
5.75	2.46	3.67	.83	2.56	.34	1.88	.16	1.44	.084	20" PIPE						22.98	71.0	14.71	24.3	10.20	10.11	900
6.06	2.87	3.88	.91	2.70	.38	2.00	.18	1.52	.095									15.52	26.7	10.77	11.20	950
6.38	2.97	4.08	1.03	2.84	.41	2.10	.19	1.60	.10	1.02	.04							16.34	29.4	11.34	12.04	1000
7.03	3.52	4.49	1.19	3.13	.49	2.31	.23	1.76	.12	1.12	.04							17.97	34.9	12.48	14.35	1100
7.66	4.17	4.90	1.40	3.41	.58	2.52	.27	1.92	.14	1.23	.05							19.61	40.9	13.61	17.10	1200
8.30	4.85	5.31	1.62	3.69	.67	2.71	.32	2.08	.17	1.33	.06									14.72	18.4	1300
8.95	5.53	5.71	1.87	3.98	.75	2.92	.36	2.24	.19	1.43	.06	24" PIPE								15.90	22.60	1400
9.58	6.24	6.12	2.13	4.26	.89	3.15	.41	2.39	.21	1.53	.07									17.02	25.60	1500
10.21	7.00	6.53	2.39	4.55	.98	3.34	.47	2.56	.24	1.63	.08			30" PIPE						18.10	26.9	1600
11.50	8.76	7.35	2.95	5.11	1.21	3.75	.58	2.87	.30	1.84	.10	1.28	.04									1800
12.78	10.71	8.16	3.59	5.68	1.49	4.17	.71	3.19	.37	2.04	.12	1.42	.05									2000
14.05	12.78	8.98	4.24	6.25	1.81	4.59	.84	3.51	.44	2.25	.15	1.56	.06									2200
15.32	14.2	9.80	5.04	6.81	2.06	5.00	.99	3.83	.52	2.45	.17	1.70	.07	1.09	.02							2400
		10.61	5.81	7.38	2.43	5.47	1.17	4.15	.60	2.66	.20	1.84	.08	1.16	.02							2600
		11.41	6.70	7.95	2.75	5.84	1.32	4.47	.68	2.86	.23	1.98	.09	1.27	.03							2800
		12.24	7.62	8.52	3.15	6.01	1.49	4.79	.78	3.06	.27	2.13	.10	1.37	.03							3000
		13.05	7.8	9.10	3.51	6.68	1.67	5.12	.88	3.27	.30	2.26	.12	1.46	.04							3200
		14.30	10.08	9.95	4.16	7.30	1.97	5.59	1.04	3.59	.35	2.49	.14	1.56	.04							3500
		15.51	13.4	10.85	4.90	7.98	2.36	6.07	1.20	3.89	.41	2.69	.17	1.73	.05							3800
				11.92	5.88	8.76	2.77	6.70	1.44	4.29	.49	2.99	.20	1.91	.07							4200
				12.78	6.90	9.45	3.22	7.18	1.64	4.60	.56	3.20	.22	2.04	.08							4500
				14.20	8.40	10.50	3.92	8.01	2.03	5.13	.68	3.54	.27	2.24	.09							5000
						11.55	4.65	8.78	2.39	5.64	.82	3.90	.33	2.50	.11							5500
						12.60	5.50	9.58	2.79	6.13	.94	4.25	.38	2.73	.13							6000
						13.65	6.45	10.39	3.32	6.64	1.10	4.61	.45	2.95	.15							6500
						14.60	7.08	11.18	3.70	7.15	1.25	4.97	.52	3.18	.17							7000
								12.78	4.74	8.17	1.61	5.68	.66	3.64	.23							8000
								14.37	5.90	9.20	2.01	6.35	.81	4.08	.28							9000
								15.96	7.19	10.20	2.44	7.07	.98	4.54	.33							10000
										12.25	3.41	8.50	1.40	5.46	.48							12000
										14.30	4.54	9.95	1.87	6.37	.63							14000
												11.38	2.40	7.25	.81							16000
												12.76	2.97	8.18	1.02							18000
												14.20	3.60	9.10	1.23							20000

PRINCIPLES AND APPLICATION OF A

SYSTEM OR STATION HEAD CURVE

A system or station head curve is essentially a graphic illustration showing the pressure required to deliver or push any given quantity of water through a given piping system.

Perhaps the best way to explain the why's, wherefore's, and mechanics of the basic principles of a system head curve is to assume an elementary example of its application.

Let us assume a pumping station is to be designed for three pumps, each to have a capacity of 375 G.P.M. The piping and friction loss value of the fittings within the system are equal to an equivalent length of 300 feet of 6" C.I. pipe. The static head, or the difference in elevation, between the liquid levels of the suction and point of discharge is 20 feet.

It is intended, during peak flows, that two or more pumps would operate. The pumps would operate in parallel, discharging through a common line.

We want to determine the pumping capacity of the station when two pumps are operating and when three pumps are in operation. The simplest and most accurate way to determine this capacity is to first plot the system head curve. Such a curve, based on the above data, is illustrated in Figure 1, attached.

In studying the curve you will note that the static head line AB was plotted to correspond to the given static head of 20 feet.

The system head curve AC is nothing more than the calculated friction loss when discharge capacities shown through the equivalent length of the given 300 feet of 6"C.I. pipe. As an example, when discharging 250 G.P.M. the loss in the system is approximately 2.5 feet; 300 G.P.M., approximately 5 feet; 500 G.P.M. approximately 10 feet; etc. These are the plotting points which determine the system head curve A.C.

Be careful to note that the system head curve starts on the static head line at zero capacity. The sum of the static head and friction head for capacities indicated are shown graphically on the system head curve AC.

Since the system head curve combines the static and friction head for any given capacity, then it is also true that it indicates the total dynamic head (T.D.H.) a pump would operate against to deliver any given capacity within the range of the curve.

In our example the pumps are rated to deliver 375 G.P.M. The curve shows (at point D) that to deliver 375 G.P.M. the pump must work against a T.D.H. of 26 feet. The next step is to select a pump to deliver 375 G.P.M. at 26 feet. From our pump curves we find that a pump operating at 1150 R.P.M. with a 9" diameter impeller will do the job.

Since we must find what capacity the pumping station will deliver when two and when three pumps are running, it becomes necessary to draw the head capacity curves for parallel operation of these pumps. This curve is illustrated in Figure 2, attached.

A curve showing parallel pump performance is

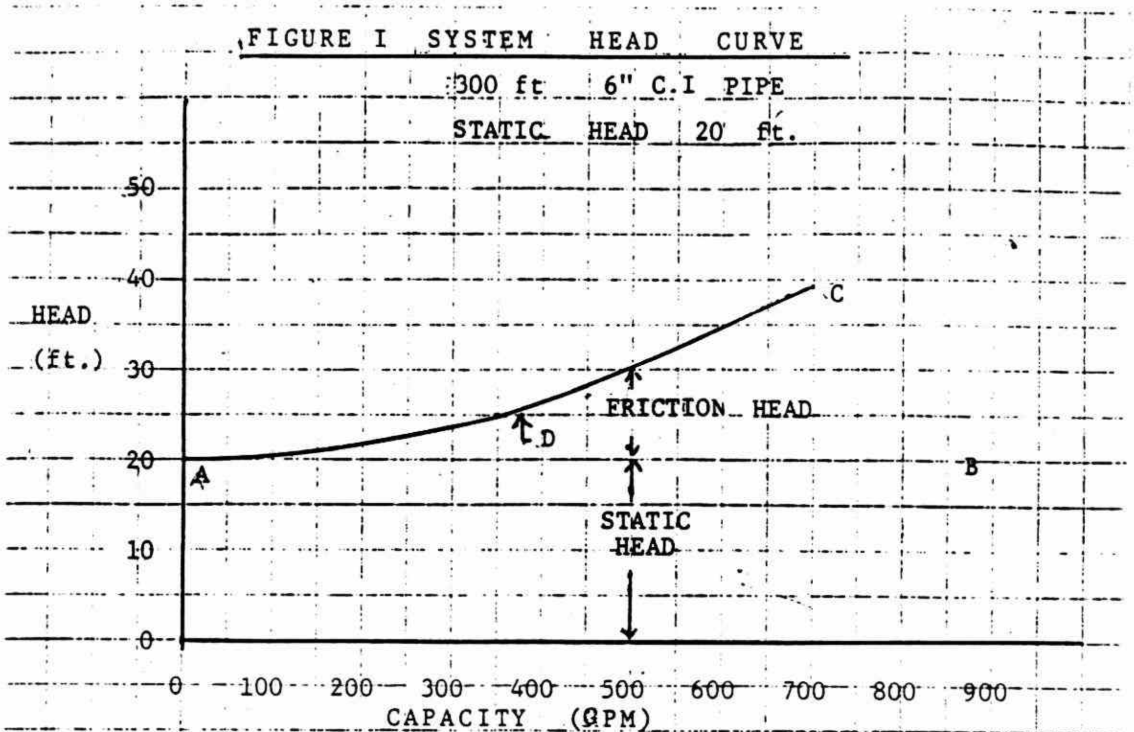


FIGURE I SYSTEM HEAD CURVE
300 ft 6" C.I PIPE
STATIC HEAD 20 ft.
50
40
HEAD
(ft.)
30
20
10
0
C
FRICTION HEAD
D
A
B
STATIC
HEAD
0 100 200 300 400 500 600 700 800 900
CAPACITY (GPM)

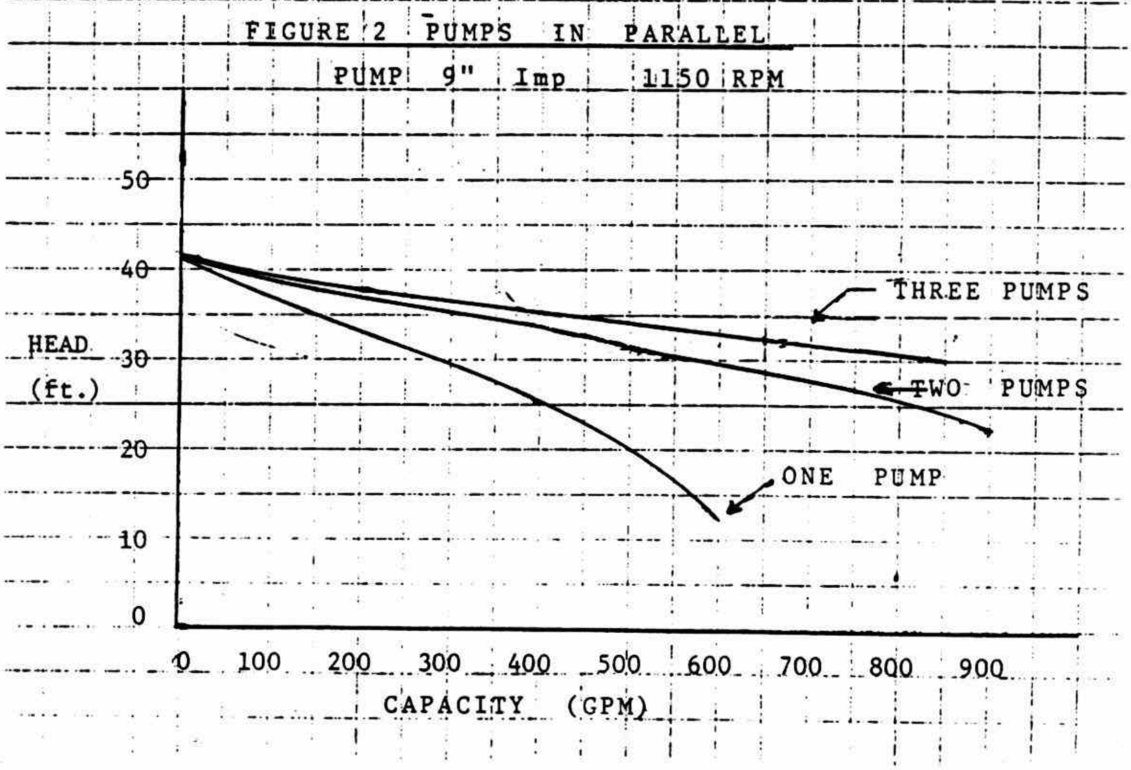


FIGURE 2 PUMPS IN PARALLEL
PUMP 9" Imp 1150 RPM
50
40
HEAD
(ft.)
30
20
10
0
THREE PUMPS
TWO PUMPS
ONE PUMP
0 100 200 300 400 500 600 700 800 900
CAPACITY (GPM)

simple and easy to compute. You will note that curve DE is the head capacity curve of the pump operating at 1150 R.P.M. with a 9" diameter impeller, which we select for the job. To establish the plotting points when two pumps operate in parallel, just double the capacity of the single pump, keeping the head the same.

For example, if one pump delivers 200 G.P.M. at 33 feet, two pumps will deliver 400 G.P.M. at 33 feet; if one pump delivers 300 G.P.M. at 29.5 feet, two pumps will deliver 600 G.P.M. at 29.5 feet; etc.

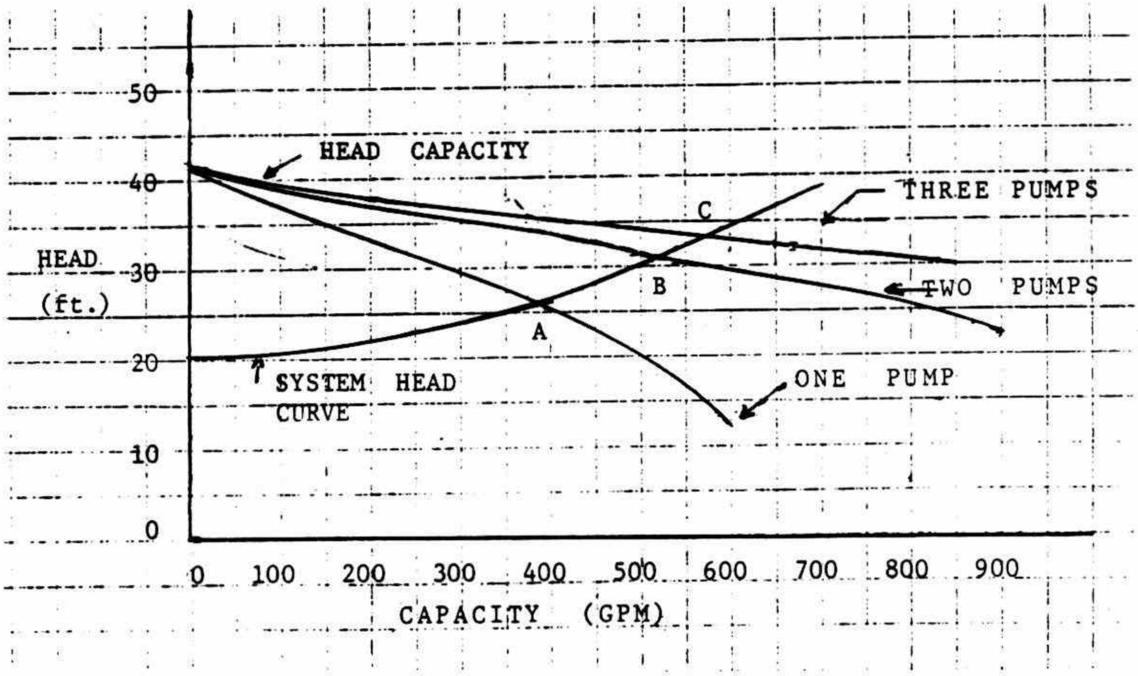
Use the same method of plotting points for parallel operation of three pumps as you did for two, except that you triple the capacity of the single pump instead of doubling it; i.e., 200 G.P.M. at 33 feet would become 600 G.P.M. at 33 feet, 300 G.P.M. at 29.5 feet would become 900 G.P.M. at 29.5 feet, etc.

By superimposing the system head curve, Figure 1, over the curve showing the pumps operating in parallel, Figure 2, we now can determine what capacities the station will deliver when two or more pumps are operating. This curve is illustrated in Figure 3, attached.

The points where the system head curve intersect the head capacity curves indicate the capacities and heads at which the varying number of pumps will operate. Point "A" shows operation of one pump, delivering 375 G.P.M. at 26 feet. Point "B" shows operation of two pumps, delivering a total of 530 G.P.M. at 30.5 feet. Point "C" shows operation of three pumps, delivering a total of 585 G.P.M. at 33 feet.

This description of the mechanics of a system head curve is only intended to show the basic principles of a system head curve. It does not imply that the foregoing would necessarily be considered a good selection of pump capacities for parallel operation.

FIGURE 3 INTERSECTION OF SYSTEM HEAD AND HEAD CAPACITY CURVES



SUBJECT:

WATER DISTRIBUTION
SYSTEM DESIGN

TOPIC: 5

Factors in Planning
Design and Construction

OBJECTIVES:

The trainee will understand the basic considerations in planning designing and constructing a water distribution system.

FACTORS IN
PLANNING DESIGN AND CONSTRUCTION

INTRODUCTION

This topic has been prepared to provide, in a summary format, an outline of the factors to be considered starting with the planning of the system, through the design and the tendering stages, including the requirements for specifications and the construction contract for a water distribution system.

PLANNING

Ideally, a water system should be planned to meet all requirements of the users under normal and abnormal circumstances. The key point to keep in mind is the user has.paid for a service and, therefore, expects it to function at all times. The service area should have two supply points so that a portion of the system could be kept in service while repairs are being made to another part of the system. The water delivered must have an adequate pressure and be excellent in terms of quality and quanity.

The area to be served is determined both as it relates to the initial system needs and the expected ultimate service area. Land elevations are important. The pressure within the system will decrease as the land elevation rises. Generally, a pressure boundary would be reached when the system pressure drops below 40 p.s.i. under normal operating conditions. Conversely, if the land elevation is lower away from the point of supply, the pressure will increase. A pressure of 100 p.s.i. is normally used as a maximum in a water system, otherwise difficulties in the household plumbing could occur. For those

lands located above the 40 p.s.i. pressure line, repumping of the water would be required, and for the lands below the 100 p.s.i. pressure line, pressure reducing valves would be required.

The water quantity demands should then be determined for the design service area, including average day, maximum day, peak hour, and fire protection needs. The average day demand in a residential area could be calculated on the basis of 100 gallons per capita per day (gpcd) and for commercial/industrial areas - 1500 to 3000 gallons per acre per day (gpad). Generally, the maximum day demand is obtained by assuming a requirement twice that of the average day flows. Fire demands are determined based on the value of the housing/stores/industrial buildings to be served by the system. The watermain system to be designed will be required to transport the highest water flow given by the maximum day plus the fire demand rate or the peak hour rate. It should be noted that the design standards do vary dependent on the type of development and the municipality.

DESIGN

The design of a water system is complex and with large systems, computers are now utilized. The minimum watermain will normally be a 6 inch diameter pipe as this is the smallest size that can adequately supply a fire hydrant. Dead end mains are avoided as much as possible but, when necessary, smaller diameter pipe may be used (2 inch) or a hydrant will be located at the end of a 6-inch main. In some instances a blow-off valve arrangement is used instead of a hydrant at the end of small diameter main. The attempt is to prevent the formation of sediment in the mains and to provide a means to flush the main periodically. Our water systems must be cleaned routinely as, despite the efforts taken to provide clean water, some sediment does occur. A similar situation exists with the purchase of gasoline for automobiles and the gasline filter must be changed routinely. Because the distribution system is designed to

operate efficiently under high flows, there is ample opportunity for sediment to occur in the main.

Hydrants are placed along the street mains at intervals ranging from 250' to 1000' dependent on the level of protection required. Valves should be placed on the lead from the main to the hydrant which normally would be left open, but can be closed at any time that it is necessary to replace or repair a hydrant without disrupting service to the consumer. Hydrants should always be located on the inside of a curve, inside of a street intersection and off-line from driveways on the opposite side of the street to reduce the chance of them being hit with an automobile. Intersection mains are also valved to enable only partial shut down of a system for repairs.

It is desirable to adopt standards for the locating of valve boxes, valve chambers and watermains within a municipality so that most could, in fact, be located without reference to an engineering drawing. This can generally be done by placing a main line shut off valve at the intersection on the extension of the property line or the curb line of the intersection streets, the locating of the watermain a set distance off the street line and, with the main being placed always on the side of streets with the odd or even house numbers, whichever seems appropriate in a given municipality. However, once a particular side of the street has been selected, it should then be maintained throughout the municipality. Curb stops for residential connections are normally located on the street line in the centre or at the corner of a lot if a double wye connection is utilized. The single family service connection today must be a 3/4" diameter pipe to the branch off at the hot water heater. As an aside, in the interest of achieving the forced conservation of water by the users, it may, in the future, be advisable to consider reverting back to the old standard of ½" service connections.

Standards of a Municipality/PUC normally apply to the use of main line valves stating where valve boxes or valve chambers are required dependent on the size of the main. It is advisable also to position the valve nut, using an extension if necessary, at a common elevation below the ground surface so that a single valve key can be used to operate all valves in the system.

Watermains must be anchored at all changes in direction sufficient to withstand the internal force due to water pressure from pushing the main apart for all mains where a push-on joint system is used. Examples of the forces applied at right angle bends is shown below:

A 6" main at 100 p.s.i. represents an endthrust of 1.4 tons

A 12" main at 100 p.s.i. represents an endthrust of 5.6 tons

A 24" main at 100 p.s.i. represents an endthrust of 22.6 tons.

It is readily apparent that as the main size is increased, the required thrust blocking increases very significantly. Reaction blocking at watermain bends can be accomplished using concrete poured in place, by using joint anchors along a sufficient length of pipe back from the bend such that the earth friction on the pipe itself is sufficient to withstand the thrust, or where the main is being constructed in a bedrock area, rock anchors may be used.

All watermains used should have a rated sustained pressure capable of at least 150 p.s.i. to provide the required soils support strength in the case of rigid pipes (ductile iron, asbestos cement, concrete) and to provide long term strength after various connections have been made to flexible pipes (PVC or PE). In cases where

large diameter transmission mains are designed, this pressure requirement is generally adjusted to suite the actual design condition. Such an approach is not, however, recommended for normal distribution mains as, despite the initial design requirement of say 70 p.s.i., the system may be required to operate at 100 p.s.i. or slightly greater due to an adjustment in the pressure zone boundary. Also, it must be remembered that all water systems are, on occasions, subjected to water hammer which is a form of shock waves that are carried along a pipe line caused by the rapid closing of a main line valve and pressures twice the normal operating pressure can be achieved.

SPECIFICATIONS AND CONTRACTS

Projects to be constructed using municipal forces do not require the preparation of project specifications or contracts. However, if the decision is made to retain a contractor to complete the construction of the project, then the project specifications and contract documents are a necessity.

Specifications

Specifications are required to fully describe the construction materials, method of construction, and the procedure to be followed in the construction of the project. The project must not be over specified. Using extra wording can lead to ambiguities and errors.

The specifications must clearly state what has to be done and, generally, all follow a similar format. The requirement for site preparation must be described and it is important that such items as the moving of hydro

poles, partial closing of a street and the maintenance of traffic requirements not be overlooked. The materials to be used in the construction, concrete, backfill, etc. should be clearly described. The materials to be used for watermains, the valves, and hydrants should be described, including the requirement for the storing and handling of all watermain materials on the project site. The flushing and disinfectant requirements must also be covered.

Contract

The construction contract is an agreement between the contractor and the owner for the construction of the project. All people named in the contract, the engineer, the contractor's representative, the inspector, etc. are all agents of one of the two parties to the contract. The engineer (owner representatives) has the job to interpret the contract requirements in any disputes with the contractor. The inspector does not have this authority, he must report only to the engineer and not take any decision taking responsibilitie onto himself. Only one person should be in a position to make decisions and, since the engineer is reponsible for the design of the project, he is normally named as having this responsibility. In cases where the engineer is unable to resolve the dispute with the contractor, then the owner is called on to make a decision.

The contract includes all necessary references to site working conditions, completion of the project, method of payment, guarantees, etc.

TENDERS

A tender is a form or proposal submitted by a contractor describing in summary form the project and the cost amount that the contractor would be prepared to construct the project for. The tender form usually lists the items included in a contract and the cost for each item. Payments are based on the completion status of each item.

Contractors may be invited to submit a tender for a project either directly by the engineer on behalf of the owner or through an advertisement in a newspaper.

Normally, a tender once submitted by a contractor, may not be withdrawn or altered unless requested by the owner. Further, the contractor must be prepared to sign a contract for the project if selected by the owner or forfeit his bid deposit. The selection of a contractor to construct a project is generally referred to as "award of the contract to______________".

RELATIONSHIP CONTRACTOR/MUNICIPAL FORCES

The contract is binding on both sides. The Contractor must do all the work specified for the contract price but he is not required to do extra work, i.e. work not called for in the contract unless arrangements are made that the contractor is paid for this work. The owner, for example the municipality, is obliged under the contract to pay for the work done, to arrange for special work to be done by others or to pay the contractor to do extra work.

Municipal forces are often required to do work in conjunction with the contractor. In these cases both parties are working for the Municipality and their co-operation will lead to lower total costs for the Municipality.

SUBJECT:

WATER DISTRIBUTION

SYSTEMS OPERATIONS

TOPIC: 6

Excavation Installation of Watermains, Site Restoration

OBJECTIVES:

The trainee Will be able to

1. Recall the basic principles in excavating trenches, installing pipe and restoring the site
2. Recall the effects of soil type on trenching methods
3. Recall the purposes of bedding
4. Define
   a. The four(4) classes of bedding
   b. Load Factor
5. Recall the principal considerations when backfilling
6. Recall the items which constitute restoration and the method(s) of dealing with each

EXCAVATION INSTALLATION AND SITE RESTORATION

INTRODUCTION

Watermains, after they have been installed and made operational, must serve two functions. They must provide a passage for the water for which they were designed; and, equally important, they must fit the surrounding ground, supporting the weight of this ground and any load on it.

The pipe, the soil around it, and any superimposed loads, all interact as the pipe performs its structural function. Knowing this, one can better appreciate the reasons for the care taken in the bedding of the pipe and the placing of backfill. The proper installation of pipe not only ensures that the utility will provide maintenance free service, but also ensures that other utilities in its locale, including the road surface, will be properly protected.

There have been cases where an improperly installed pipe has resulted in collapse and complete shutdown of a utility, and often on the restriction of use of other facilities. Therefore, pipe is not to be buried and forgotten; it must be both carefully made and carefully installed, following certain principles.

No matter how big the job, watermain construction can be broken down into three major phases, namely, excavation of the trench, installation of the pipe and backfilling of the trench. Cleaning disinfecting and testing are considered in other topics.

TRENCH EXCAVATION

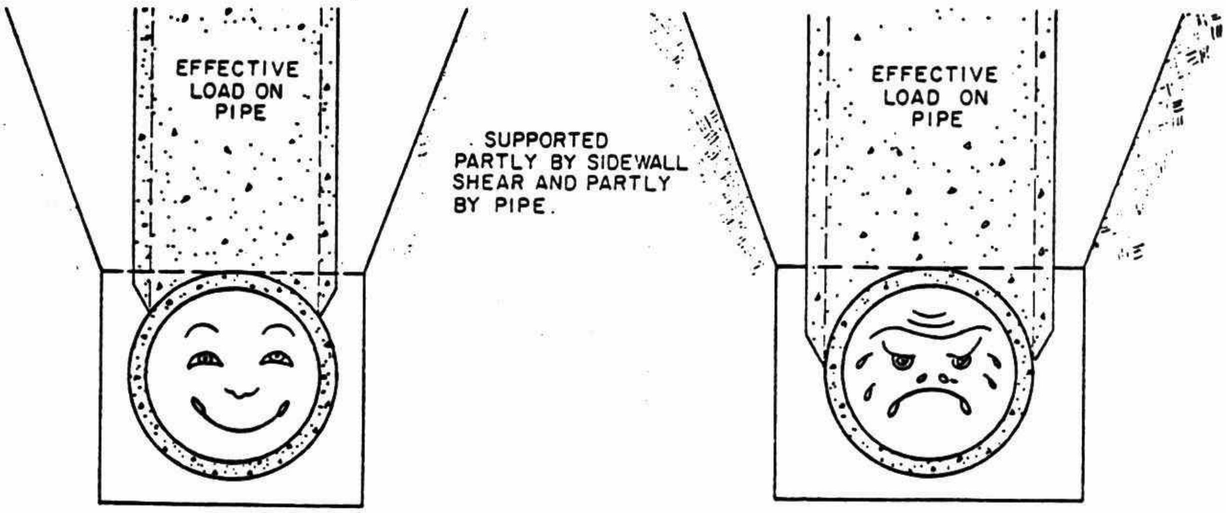
General Consideration

Excavation of the trench should not be carried too far ahead of pipe laying in order that the possibility of flooding the trench during rainy weather and cave-ins caused by ground water can be minimized. Long sections of open trench may cause disruptions and inconvenience to local residents and certain municipal services such as ambulance and fire fighting.

The width of the trench must be sufficient to permit proper laying and joining of the pipe. It is a common practice for the minimum width of the trench to be 300 mm greater on either side than the outside diameter of the pipe to enable the workmen to tamp the backfill around the bottom half of the pipe. The width of the bottom of the trench should never be greater than the width at the top because of the danger of side collapse.

Trenches over 1.5 metres deep must be sheeted where the ground is poor and for the safety of the workmen except where solid or good soil conditions will permit slashing the trench in the shape of a Vee. In case of slashed trenching, the vertical wall may not be more than 1.2 metres high and the banks of the remainder of the trench must be sloped at a one to one ratio. Specific requirements for trenching, the installation of sheathing or the use of trench boxes are set out in the Construction Safety Act, Ontario Regulation 419/73, Part IV and are enforced through the authority of the Ministry of Labour.

The following examples indicate the effect of the additional load placed on a pipe as a result of the trench width being increased:



NARROW TRENCH
LESS PIPE LOAD

WIDE TRENCH
MORE PIPE LOAD

For suggested trench widths see M.E.A. Model Drawing No. 411, attached as Appendix "A".

The tendency is to dig firm soils with trench walls which do not have enough slope and are too narrow and, on the other hand, to dig wet silts or free-running soils generally too wide. Soil types, water content, slope stability are constantly changing factors, requiring modifications in trenchings methods.

1. Firm clays and till soils with below optimum moisture can usually be excavated easily and safely but require careful control during backfill.

2. Dry sand requires careful observation during excavation since it can slip or run easily and yet backfilling with it is comparatively easy.

3. Dry silt behaves like clay, but is not too common, and wet silt which is all too common behaves in unpredictable and hazardous ways and often requires special treatment.

4. Most soils contain portions of sand, silt, and clay and, although it is an oversimplification it is generally true that excessive water and excessive silt are the prime cause of excavation and backfill difficulties.

The bottom of the trench should be left true and even, so that the barrel of the pipe will have a bearing for its full length. If firm support of the pipe by underlying soil is established only over a narrow width, as with a round pipe on a flat bottom trench, the intensity of the load beneath the pipe will be considerable, and failure more likely. Distribution of the load over a wider area will reduce the load intensity beneath the pipe, and, consequently, reduce the likelihood of failure. It should be noted that shale or rock foundations are particularly critical in regard to load concentration.

Storage of Excavated Material

It is important to store material so as not to directly damage trees, lawns, etc., but it is also important to judge what might happen during a rain storm or extended exposure to the elements. Stored material should be kept back from the wall of the trench to prevent sur-charging, and possible cave-ins, or subsidence cracking. This is a danger signal indicating weak trench bottom and a need for urgent action by the person in charge.

Excavating Equipment

Selection of appropriate equipment is important. Machines which are too big cause unnecessary damage to trees, poles, etc., and machines which are too small move the job too slowly, which is not only uneconomical but may also cause such problems as settlement due to frozen backfill or side-slope instability. Bucket widths should also be checked to minimize excavation and maintain side support. Most buckets can be changed very quickly or if necessary an appropriate size can be rented.

Most trench work today is being done by hydraulic backhoes. These provide excellent control; they can be used in most sheathing situations as well as in "V" trench, and come in a variety of sizes. In very wet tight-sheathed conditions some prefer a clam bucket which is slow but is sometimes a last resort in a deep trench, and may be accepted.

Use of drag lines generally should be discouraged due to the wide area required for storage of material and considerable resultant damage. Some prefer drag-lines on wet sandy work but very poor grade control and considerable disturbance of the trench bottom invariably results in a poor job.

BEDDING

General

The purpose of bedding a pipe is two-fold:

1. to provide firm continuous support for the pipe to maintain the grade set for the pipe line;

2. to provide the soil side support for the pipe to enable the pipe and the soil to work

together to meet the design load requirements.

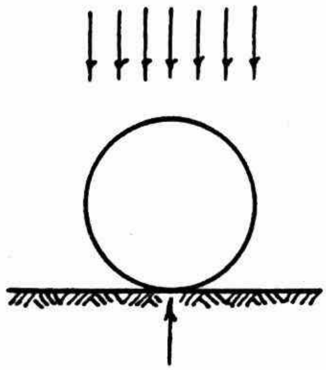
If a pipe is set on a flat foundation without any bedding there is a high load concentration at the bottom of the pipe. If the pipe is bedded over 50% of the diameter of the pipe, the pipe can support 36% more weight than it could without any bedding. Increase the bedding to 60% of the diameter the pipe can now support 73% more weight than with no bedding. Extend the bedding to 100% of the pipe diameter and the pipe will now support 114% more weight than the original unbedded pipe. Add good side fill compaction to bedding under 100% of the pipe diameter and you now have 150% of the load-carrying capacity that you had when you started with an unsupported pipe. See figure 6-1.

Classes of Bedding

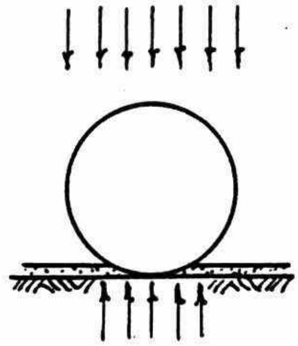
There are four classes of bedding commonly used - classes A, B, C and D. The best class of bedding (Class A) enables a given pipe to carry a load three times as much as that load the pipe could carry in a three-edge bearing test. The worst class of bedding (Class D) enables the pipe to carry little more than it would in the three-edge bearing test. This ability of a bedding to increase the load-carrying capacity of a pipe over its load-bearing capacity in the three-edge bearing test is measured by a term called the load factor. If a certain bedding allows a given pipe to carry twice as much load as it can carry in the three-edge bearing test, the load factor is 2.0. Similarly, if a bedding allows a pipe to carry 3.0, 1.5 or 1.1 times as much load as that pipe in the three-edge bearing test then that bedding would have a load factor of 3.0, 1.5, or 1.1 respectively.

Class 'A' Bedding

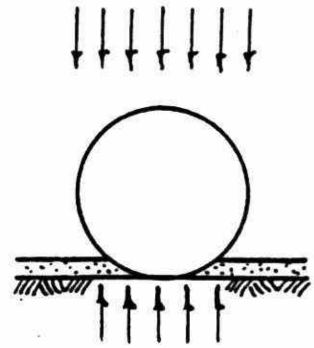
Generally specified as a concrete cradle under the pipe extending approximately half way to spring line. Its load factor is 3.0.



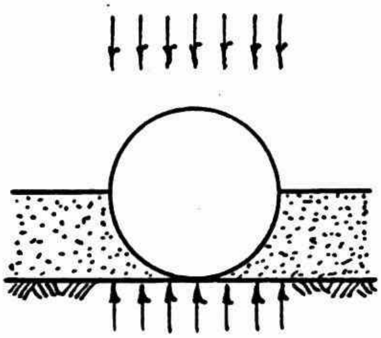
Pipe set on flat foundation without bedding results in high load concentration at the bottom of the pipe.



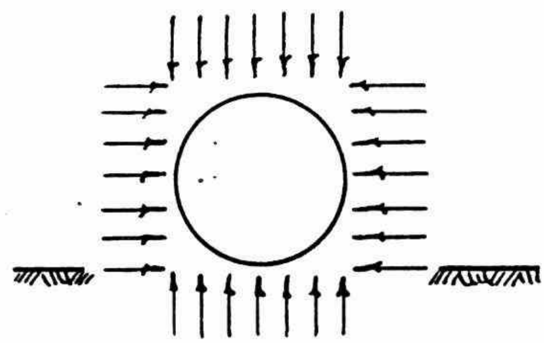
Bedding pipe over 50% of dia. results in 36% increase in supporting strength.



Bedding pipe over 60% of dia. results in 73% increase in supporting strength.



Bedding pipe over 100% of dia. results in 114% increase in supporting strength.

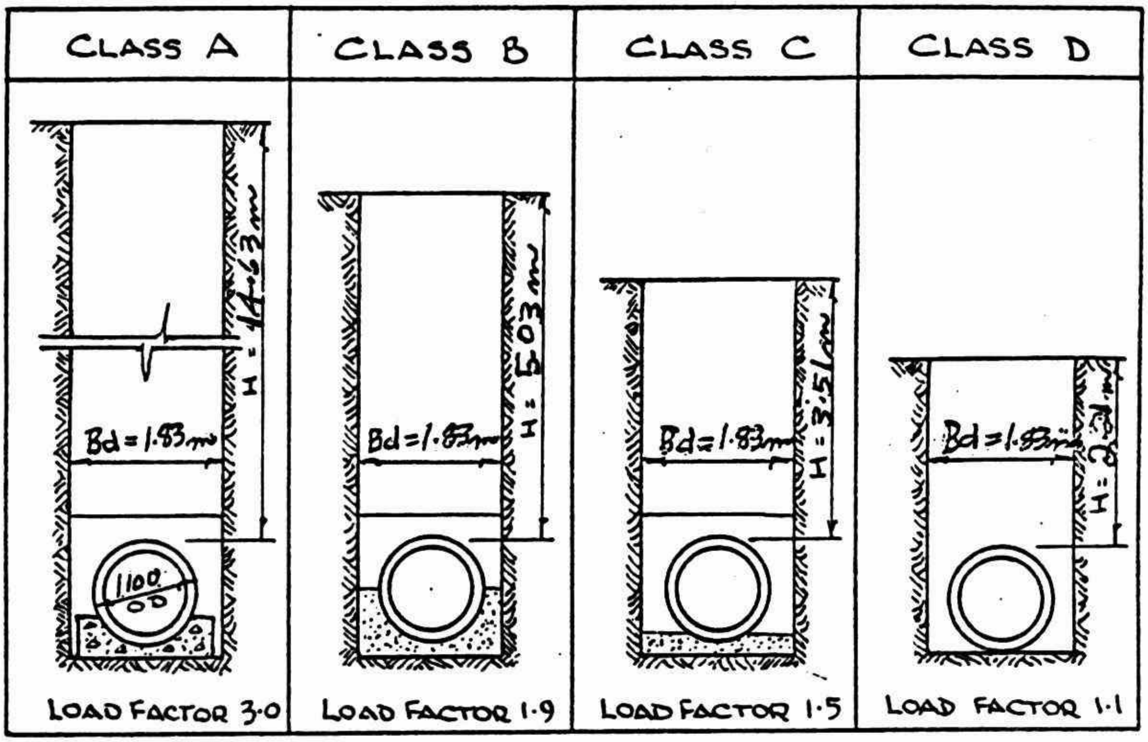


Bedding pipe over 100% of dia. and good sidefill compaction results in 150% increase in supporting strength.

CORRELATION OF BEDDING AND SUPPORTING STRENGTH

Courtesy OCPA

FIGURE 6-1



Allowable fill heights for various beddings, 900mm.
Dia. CSA A257.2 Class III Trench Installation

Figure 6-2 (OCPA)

Class 'B' Bedding

Generally specified as a well compacted granular cradle extending out to the walls of the trench and up to the spring line of the pipe. Its load factor is 1.9.

Class 'C' Bedding

Generally specified as shaping the bottom of the trench to receive the pipe. Its load factor is 1.5.

Class 'D' Bedding

Basically burying the pipe with no preparation of the trench bottom. Its load factor is 1.1.

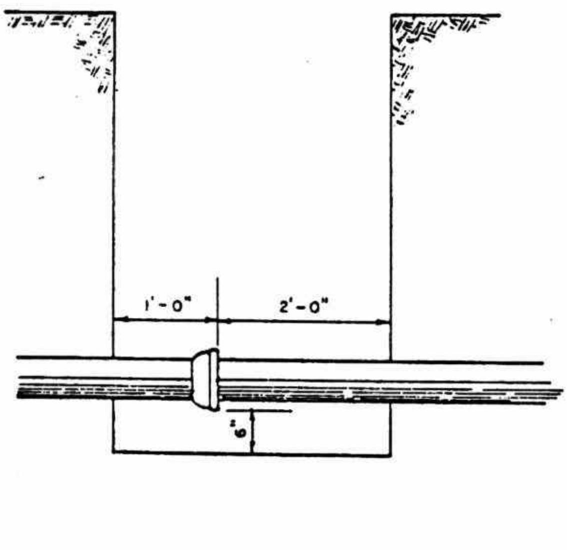
Figure 6-2 illustrates the effect of the various bedding types upon the depth of cover over a pipe with the only variable the bedding type.

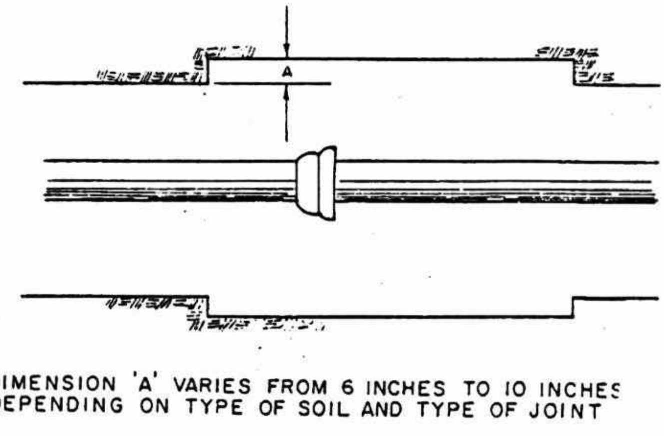
Bedding Procedure

The primary requirement when bedding a pipe is to have a stable and uniform foundation. It should be smooth and free from large stones, rock, boulders, construction material debris, large clods of earth and frozen material.

A 75 to 150 mm layer of bedding material is usually spread on the original trench bottom in order to bring the bedding up to grade for laying the pipe. The pipe barrel must be given even continuous bearing for its full length. There should be no high or low spots on the bottom of the trench nor should couplings or bells rest on the ground. The above cause point loads which can result in breaks in the pipe. The high and low points can be avoided by levelling the trench bottom and digging holes under the bells or couplings if necessary.

At each joint it is necessary to provide a bell hole of sufficient size to insure proper joint making. Digging bell holes so small that the jointer cannot use his tools is false economy. On the other hand, bell holes which are too large result in undue stress on the pipe. Experience has shown that large bell holes, dug with a ditching machine, place undue stress on small diameter pipe, resulting in breaks due to extra and unnecessary beem action. The following diagram shows the general dimensions of bell holes for bell and spigot pipe:





DIMENSION 'A' VARIES FROM 6 INCHES TO 10 INCHES DEPENDING ON TYPE OF SOIL AND TYPE OF JOINT

Once the trench bottom has been shaped properly and the bell holes dug it is necessary to compact the material under the haunches of the pipe. This is a critical part of the operation. Usually this is done with hand tampers. In large diameter pipe it is usually best to shape the trench bottom to fit the O.D. of the pipe. After the material under the haunches of the pipe has been installed satisfactorily, bring the rest of the bedding up to the required height in shallow lifts that are properly mechanically compacted.

Bedding Material

The best bedding material is a well graded granular material up to 19 mm in size free from lumps and frozen material. In rock trenches it is best to use a 19 mm clear stone so that the bedding material cannot wash away down fissures in the rock which could happen with a bedding material containing fines. Also, clear stone is recommended in wet conditions.

Principal Considerations for Bedding

1. Use 19 mm maximum size granular material
2. When bedding plastic pipe, it is paramount that the bedding material is properly compacted out to the trench walls since a flexible pipe uses the strength of surrounding earth to help carry the load.
3. When installing concrete cradle (Class 'A' bedding) in a rock cut make sure there is a space between the walls of the trench and the concrete.
4. Do not use fine bedding material in a trench cut through rock.

Pipe should be carried around underground obstructions, such as sewers, conduits, piers, etc., using special

fittings where necessary. Pipe should not be allowed to rest on any unyielding structure, nor should it be called on to support another structure. Pipe should not be laid in a manner that will cause it to act as a beam. It should not be poured solid in concrete walls, footings, piers, abutments or other immovable objects, as the weight of the backfill and settlement of the trench often cause the pipe to act as a cantilever beam, with resulting failure.

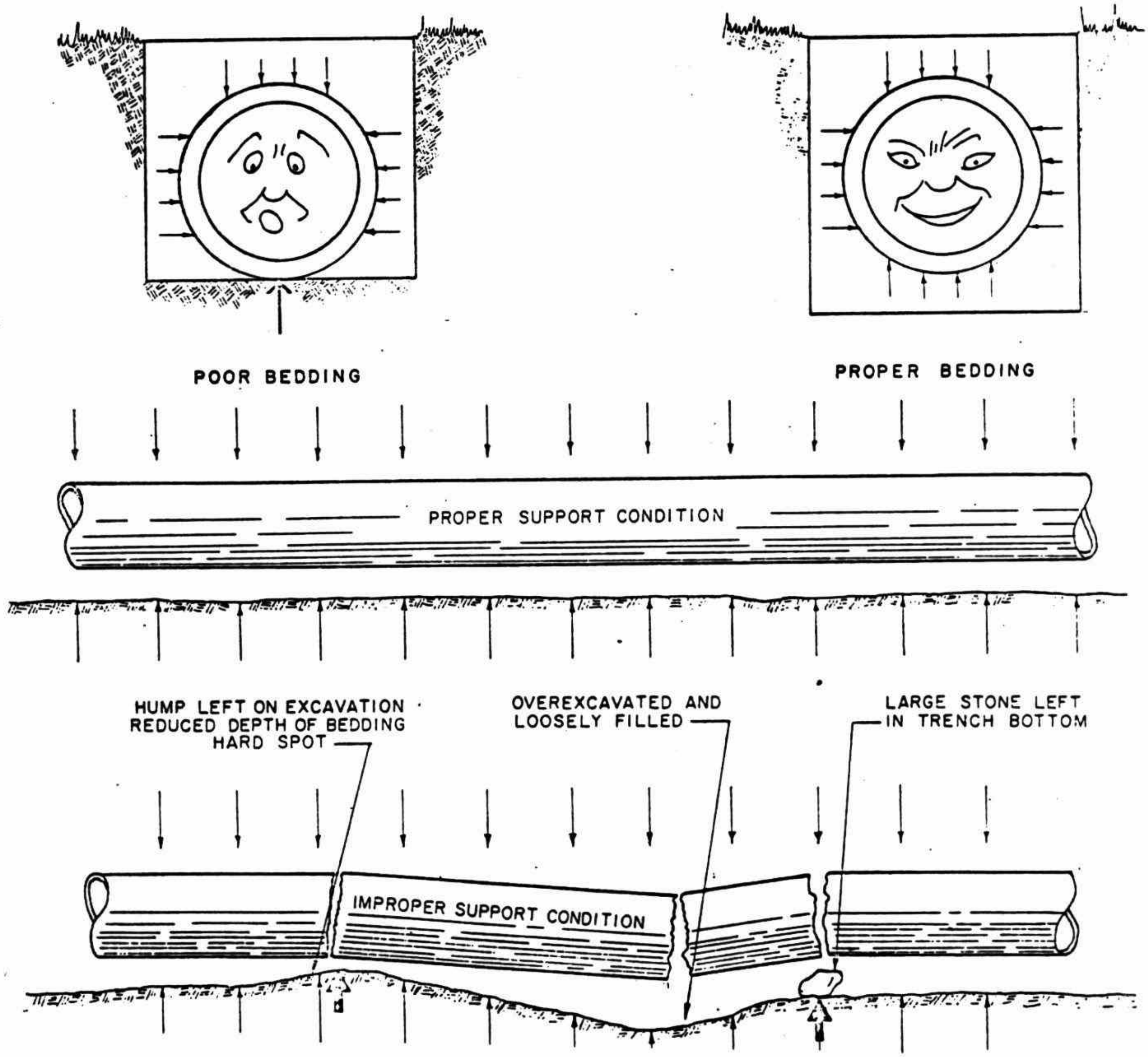


FIGURE 6-3 POOR AND PROPER BEDDING

Sleeves or special wall castings should be used at the junction with these heavy subsurface structures.

Figure 6-3 illustrates the effects of the intensity of the load on a pipe by comparing poor bedding and proper bedding.

PIPE LAYING

When the trench bottom has been prepared with the required bedding material, the pipe should be lowered into the trench by mechanical equipment, if possible, and not just rolled into the trench from the top. Smaller diameter pipe, up to possibly 12 in. diameter, may be lowered into the trench by taking a turn of rope around each end of the pipe while standing on the other end of the rope and then letting the rope out until the pipe rests on the bottom of the trench. Larger pipe sizes are best handled by means of power equipment.

Before the pipe is placed in the trench, it should be swabbed or flushed out to ensure that no dirt or foreign material gets into the finished line. Trench waters should be kept out of the pipe, and the pipe ends kept closed by means of a plug whenever work is not in progress.

The laying of the pipe is not completed until the backfilling operation has progressed to the point where the pipe is surrounded with the specified backfilling material. This is often an imported sand or granular material. However, suitable existing soil may be used for this operation, provided it is free from large stones, and does not contain any deleterious material such as rotting vegetation, roots, etc. This material should be placed at the sides and over the pipe, and must be compacted to a condition equivalent to that in the adjacent undisturbed soil. The depth over the pipe of this bedding material is normally 12 in. for smaller pipe sizes and 18 to 24 inches for larger diameters.

BACKFILLING THE TRENCH

Considerations

One phase of pipeline construction that is apt to receive casual attention is backfilling without the realization that settlement of trench due to bad backfilling procedure may add considerable costs to maintenance.

It is, therefore, important that the backfilling shall be done properly and that adherence to the following points be maintained.

1. Use only clean, washed sand or selected soil for the first layer of backfill. The first layer of backfill should not exceed one half the diameter for large diameter pipe or 300 mm for small diameter pipe, placed above and/or compacted around the upper half of the pipe.

2. Big rocks, boulders, construction debris and frozen backfill material shall not be used.

3. The remainder of the trench shall be backfilled by placing the material in layers and compacting it thoroughly.

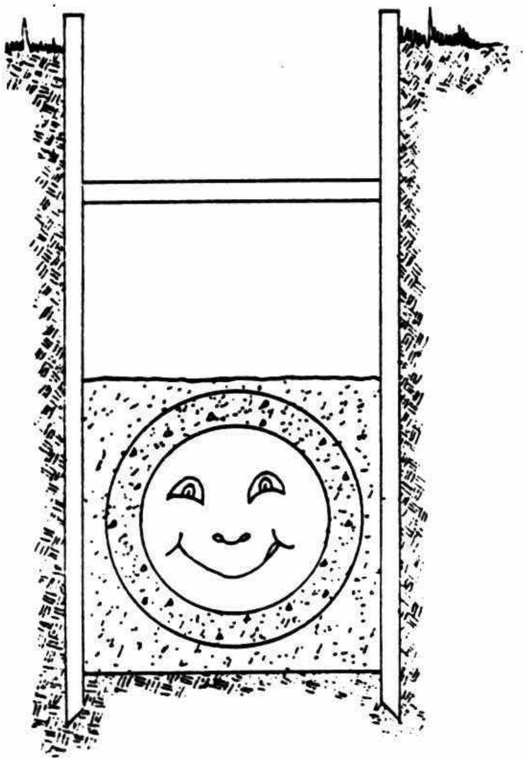
4. Compaction methods must ensure that all voids caused by removal of sheathing are filled.

5. Sheathing which extends below the invert of the pipe cannot be withdrawn without disturbing the pipe bedding and should be cut off near the top of the pipe.

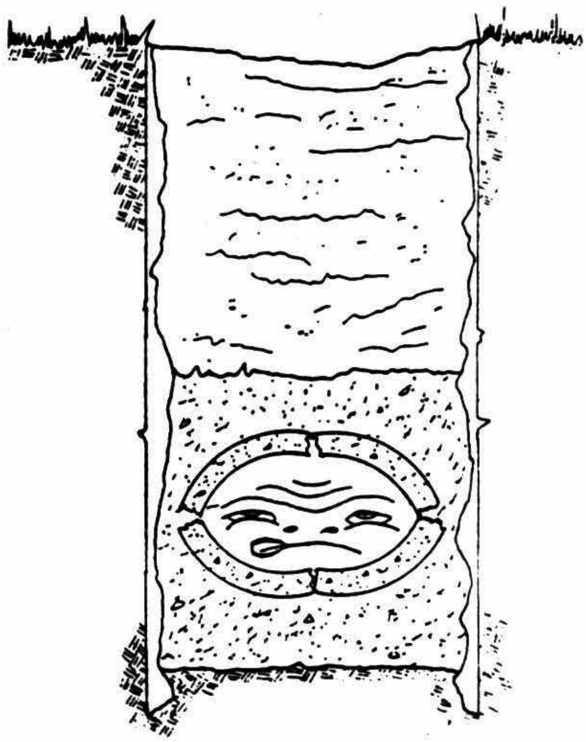
6. Where poor ground conditions exist up to the surface, it may be necessary to leave sheath-

ing in place for the whole depth except for, say, the top two feet in order to maintain stability of the installation.

The following sketches illustrates future trench settlement when sheeting is improperly removed:



SHEETING IN PLACE AND
TRENCH PARTIALLY BACKFILLED



SHEETING PULLED AND VOIDS
IMPROPERLY FILLED AND COMPACTED

Backfill Equipment

The important consideration in backfilling is to achieve a balanced operation. A small bulldozer or loader feeding a self-propelled vibratory roller is often a good combination. Trying to utilize a machine for backfilling which also doubles as a crane for lowering pipe or drawing

stone or whatever, is a mistake. Backfilling to meet a specified density is <u>the</u> most important part of the work in terms of extra cost to the employer if it is not done well.

The person in charge should insist on the backfilling being done gently, in layers of a depth within the easy capability of the compactor. Layers may be sloped, provided the compactor can work on the slope.

It may also be necessary when compacting in sheathed trenches to withdraw the timbers in stages equivalent to the layers of earth being placed. Settlements in such trenches are particularly serious because compaction is difficult and the material tends to bridge to the vertical walls but ultimately a settlement does occur.

Types of compacting equipment are many and varied but the following summary of appropriate applications may be useful.

1. Irregular Drum Tampers - clays, tills, silts.
2. Hand Controlled Plate Tampers - sand in shallow lifts.
3. Boom-Mounted Plate Tampers - clays or sands in deep, narrow trenches which preclude the operator's entry into the trench.

Generally speaking all of the above equipment is available in vibratory or static models. A vibratory type is usually preferable when the moisutre content is less than the optimum percentage determined from a "Proctor" test. Static machines usually require more passes, but in over-optimum conditions they may be the only practical alternative which will not get stuck.

<u>Backfill Problems</u>

Even with the best equipment and the best intentions, one may still not achieve acceptable results.

Material which is too wet or above optimum moisture presents a difficult situation. One approach is to note the "in-situ" density of the wet soil and then try to compact to this density. Another is to insist on a total compactive effort to the extent that no visible voids are present and this may produce tolerable results. However, as soon as moisture content exceeds optimum by more than about 3% it is essential that the person in charge obtain expert advise for whatever concessions may be given. *Never act alone*.

Frozen ground is also a major problem and if large frozen lumps are included in the backfill it is an absolute certainty that settlement will occur.

Special problem areas also exist near manholes or valve chambers or other obstacles in the ground. Using granular backfill in these areas is one answer but this also requires compaction.

The use of fragmented rock as backfill should be avoided. However, where no other material is available it is essential to mix sand, gravel, or crushed rock with the rock to fill all voids. It is also essential to place a layer of fine material over the pipe to prevent damage.

Backfilling peat bogs or other very light soils presents a very special condition. It can be shown that the weight of the pipe is less than the material displaced and, theoretically it should not settle. However, it is necessary to ensure that the weight of the soil being used as backfill does not exceed the weight of the soil removed and settlement may be induced due to compression of the underlying undisturbed peat.

The backfill should not be "topped-off", expecting settlement to make room for road base or topsoil thickness.

It is not only neater and cleaner to restore as the job continues, but it also imposes an obligation on the contractor to obtain good compaction to avoid making up settlements with costly surfacing materials.

RESTORATION

Introduction

Many years ago, restoration was minimal. Poor compaction, a little bit of stone and a surfacing of emulsion was acceptable for a roadway. Persons fronting the jobs or the maintenance division of the local Works Department were expected to look after ditch and grass restoration and the continuing maintenance or filling in of the slowly settling trenches. Trees were ripped out or the roots were cut causing lingering death. They were seldom replaced or properly pruned and fed. Stream beds were silted in and littered with construction debris, which, hopefully was carried away with the next storm. The standard of restoration, in the minds of the area politician and the ratepayers, determine whether the job has been successful or has been completed unsatisfactorily. Those involved will be informed, in no uncertain words, if the job appears unsuccessful. Good restoration is the "icing on the cake" of any construction job and it reflects on the personal reputation of the Project Supervisor and the workers. Because restoration generally is done at the end of a project and, at that time, everyone is in a hurry to finish and go about other business, it is quite often given second grade status.

Restoration Considerations

Assuming that the job is started and on its way to completion, restoration includes the following items:-

1. <u>Backfilling of trenches</u>: Depending upon the location, trenches may be backfilled with granular

or native material and compacted to a specific Proctor density. If they are not properly compacted, they may settle at any time, from the next rainstorm to many years later. Sagging trench cuts are one of the major nuisances faced by maintenance departments. Many bitter words are passed back and forth by the workmen about the ancestry of those involved in the restoration which they are again restoring.

2. <u>Asphalt or hard surfacing</u>. It is best to save all hard surfacing work to the very end of the job. In fact, many municipalities request temporary repairs with cold patch and wait at least six months before performing a permanent repair. This gives the trench a chance to settle. Care should be taken during construction that all road surfaces be cut vertical to the horizontal plane and in as straight a line with the trench as possible. This saves recutting and widening of the area to be restored.

3. <u>Sodding or spraying of grass</u>. A good grade of sod or grass should be used. This should be placed over a thin layer of topsoil. Sod is usually used for lawn and boulevard restoration in urban areas. It <u>must</u> be constantly watered until there has been a reasonable catch, usually after about a month. Grass seed is sprayed on as a mulch in more rural areas such as fields and ditches. This does not require watering but is slower than grass to take and may require respraying of spotty areas at a later date.

4. <u>Ditches and Culverts</u>. These always seem to be ignored. Ditches are destroyed and only marginal efforts are made to bring them back to original shape. Culverts are allowed to fill in with silt or construction debris or have their ends bashed about by construction equipment and then just

left. Possibly this is because they are in more rural areas. Check the ditches including culverts in the area to make sure they are still working properly. Remember, a plugged ditch in a heavy storm could flood out the surrounding area.

5. Trees and Shrubs. Damaged roots on a tree could kill it up to five years after completion of the project. When a tree is damaged, it must be cared for. Damaged roots mean the tree must be fed for several years and the limbs must be cut back. Damaged bark allows the tree to fall prey to insects, disease and fungus, any of which could bring its eventual downfall. A qualified expert must be brought in to take care of any damage done to trees. An amateur might only aggravate the situation.

6. Utilities. These must be properly located prior to initiation of the project, supported during construction and in the event of any damage will have to be properly restored.

7. Curbs, gutters and sidewalks: As previously make sure that these items are not broken prior to construction. When reconstructed, they should match as nearly as possible the existing curbs and sidewalks, e.g. the texture finish of the new walk should match the old walk.

8. Machinery and Office Sites. Oil and gasoline must be cleaned up, all construction structures removed, the ground graded, top soil added and brought back to its original grade and condition.

9. Watercourses and slopes. Slopes which have been destroyed must be structurally restored, possibly with sod and rip-rap. Stream beds silted in with

mud and debris must be cleaned out. Check the condition of stream beds a considerable distance down stream as debris is carried far from the actual construction site.

10. Roadway Clean-up. Any construction will track dirt and dust over the various roads being used. During wet weather, arrangements should be made to properly wash the mud from the wheels of the trucks at the site before it is tracked throughout the municipality. During dry weather, dust is formed upon the roads. It must be swept or shovelled from hard surface roads and graded to the shoulders or be treated with calcium on gravel roads. Do not place calcium on the dust on hard surfaced roads as it creates a muddy slick and could be particularly dangerous for cars braking and turning.

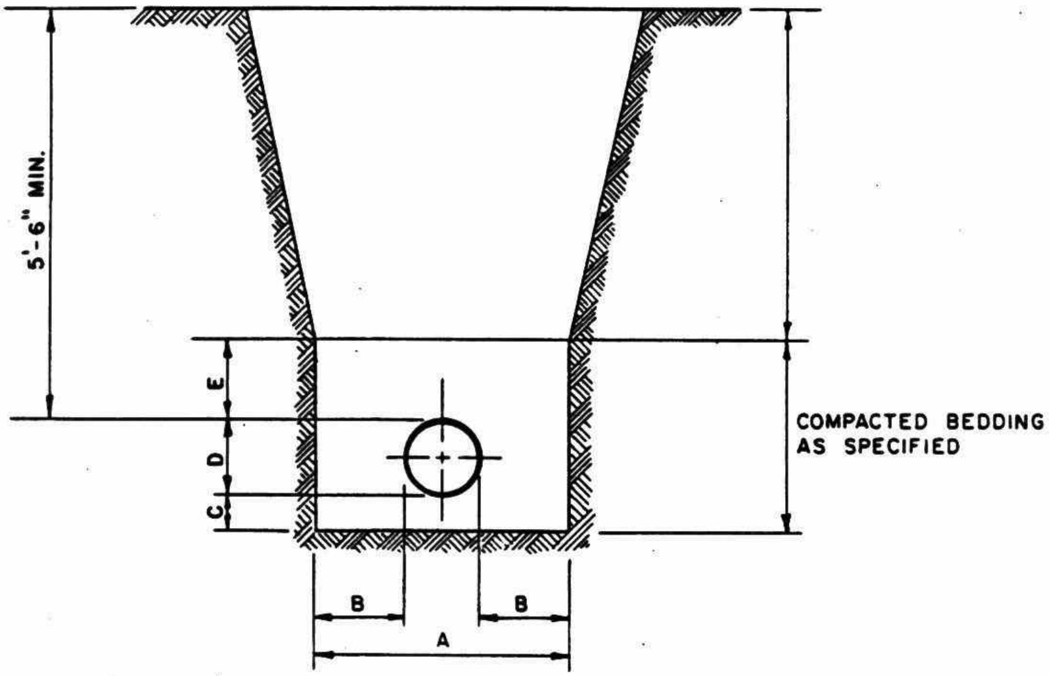
11. Traffic. Traffic diversions should be arranged. Pre-warning signs should be placed in advance of the project site. When necessary, temporary roads should be built. When construction is complete, restoration involves removing signs and filling in the holes, removing the temporary roads and putting the area back in original shape by grading, sodding, etc.

12. Garbage and snow plowing. When working on streets, these services must be maintained.

13. Miscellaneous. All construction debris along the site of the project must be removed; private driveways, walks, fences, lawns and private appurtenances put back in shape; the area cleaned up and given a good sweeping.

The weather plays a major part in restoration. Sod and other plants are best put in during the Spring and Fall. Asphalt and concrete is best placed during the warm weather. Very cold weather precludes much restoration other than granular backfill and debris clean-up.

MEA MODEL No.		411	
Date	Feb.1974	Rev.	



WATERMAINS			SERVICES
SIZE OF PIPE	4" TO 12"	14" & 16"	3/4" TO 2"
A	"D" + 1'-6"	"D" + 1'-6"	2'-0" MIN.
B	9" MIN.	9" MIN.	—
C	6"	9"	4"
D	O.D. OF PIPE	O.D. OF PIPE	O.D. OF PIPE
E	1'-0" MIN.	1'-0" MIN.	4"

NOTES:

(1) DIMENSION "C" MAY BE ZERO FOR DUCTILE IRON PIPE IN UNDISTURBED SOILS OTHER THAN ROCK OR UNYIELDING SOILS.

MUNICIPALITY:

WATERMAIN AND WATER SERVICES

BEDDING DETAILS

SUBJECT:

WATER DISTRIBUTION SYSTEM COMPONENTS

TOPIC: 7

Pipes and Joints

OBJECTIVES:

The Trainee will be able to

1. Recall the uses, advantages and disadvantages of different types of pipe used in a watermain
2. Recall the purpose of pipe coating/lining
3. Recall the methods and considerations related to the handling and storage of types of pipe used in watermains
4. Identify typical joint design
5. Recall important considerations related to jointing pipe

WATERMAIN PIPES AND JOINTS

GENERAL

The present day water transporation system normally uses cast iron pipe, asbestos cement pipe, ductile iron pipe, steel and reinforced concrete pipe and plastic pipe. New materials and compositions are constantly being developed, and these may find more extensive use in the future. The type of material used in any particular watermain depends on the analysis of a combination of factors such as the economy (material and installation), the strength, and the anticipated life and maintenance of the pipe material.

Perhaps the most common pipe used to date in the modern water system has been the cast iron pipe, and it is interesting to note that of all the cast iron pipes installed over the past 100 years or so, 90% of these mains are still in service. In recent years, there has been a marked switch from the cast iron to ductile iron pipe, and it seems inevitable that the manufacture and availability of cast iron pipe will decline in the future.

PIPE DESIGN

In all cases, the strength of a pressure pipe must be sufficient to withstand the combined forces of the internal hydrostatic pressure and the external loads imposed on it. The internal pressure is made up of two components: first, the nominal working pressure; and second, the water hammer that may be caused by the rapid closing of valves, the stopping of centrifugal pumps, or other causes. The normal water pressure depends on local conditions and

requirements, and is usually in the 40 - 100 p.s.i. range. The external load on a pipe is made up of (1) the weight of backfill; and (2) the weight of the traffic plus impact, and is influenced by trench conditions.

Reference should be made to the A.W.W.A. standard specifications for pressure pipe material. A partial list of these is at Appendix A. In these specifications the method of design and manufacture and installation is covered in detail. Reference should also be made to the literature issued by the pipe manufacturers. These pamphlets and booklets, in most cases, contain extracts from A.W.W.A. specifications, and are useful to the designer in making his pipe selection.

TYPES OF PIPE

Cast Iron Pressure Pipe

These are manufactured by centrifugal casting in metal molds. The molds are water-cooled and rotated at high speed as the molten metal is poured into the mold. The bell end of the pipe is formed around the sand core, which is fitted into the bell end of the rotating mold. The standard length of a cast iron pipe is 18 feet, and the pipes are cast in diameters from 4 in. to 60 in.

Ductile Iron Pipe

Ductile iron pipe has the same dimensions and joints as cast iron pipe, except for the pipe thickness. The main differences is in the material, which is a modified molten gray iron with a magnesium alloy addition. This produces a pipe with ductility; that is, the ability to stretch or deform plastically when stressed past its yield point.

It has also a high tensile strength and an excellent resistance to shock or impact. All cast iron or ductile iron pipe is finished with a standard protective coating of bituminous paint. In recent years, this has become a most popular pipe, and is rapidly replacing cast iron pipe for new works in many installations.

Asbestos Cement Pipe

This pipe is made from a mix of asbestos fibres, portland cement, silica and water. The cement imparts the compressive strength and durability. The asbestos fibres provide the tensile strength and the silica is added to facilitate the curing process. The asbestos cement slurry is sprayed to the surface of a rotating mandrel and successive laminations are built up. The pipe on the mandrel then goes through a curing process. The pipe ends are subsequently machined for pipe couplings. Asbestos cement pipe has certain advantages over cast iron and ductile iron pipe in that it is corrosion resistant and has a higher flow coefficient. However, since the standard length is 13 feet long, there are more joints to be made than in the case of cast iron or ductile iron pipe.

Plastic Pipe

The most popular type of plastic pipe now used in the water works industry is the rigid P.V.C. pressure pipe (polyvinyl chloride). The pipe is normally specified by the Standard Dimensional Ratio (SDR) which equals the outside diameter divided by the wall thickness. The principle advantage of this pipe is its extremely light weight compared to other types of pipe, its flexibility, its ease in handling and jointing, and its ease in cutting. Like asbestos pipe, it is corrosion resistant and has a high flow coefficient. This pipe can be supplied to any reasonable length.

Polyethylene pressure pipe is also used to some extent in the water industry for water main distribution. This pipe is normally used in special conditions where an extremely flexible line is required through unstable ground conditions, or particularly difficult installation conditions, where the advantages of the great flexibility of the material can be utilized to full advantage. There is no conventional jointing system for this pipe material, and to date it requires a special butt fusion welding operation to join two lengths of the pipe. This type of jointing is a specialist operation, and may require the employment of a special contractor to carry out this work. Due to this factor, and to the wall thickness of the pipe, it is likely to be a more costly installation than for more conventional materials. However, there is definitely a place for this material in the water works industry.

Reinforced Concrete Pipe

This pipe is made from steel and concrete. The pipe consists of a continuous steel cylinder 16 feet long, electrically welded with zinc coated steel bell and spigot. The cylinder is lined with a coating of concrete applied centrifugally. A structural casing of reinforced concrete is applied externally to give the complete wall thickness required. The pipe is normally manufactured from 14 in. diameter and up. Reinforced concrete pipe is usually used on long transmission pipe lines, and is not normally used for local distribution systems, since the pipe has to be tailor-made, complete with special fittings for a particular job. This material provides a reasonably priced installation, which is relatively trouble free; however, it is difficult to repair compared to other pipe materials, and much more costly to tap, if a small diameter connection is required.

PIPE COATINGS AND LININGS

Metallic pipe is subject to corrosion after installation. This can be both a chemical corrosion and an electrolytic action caused by stray currents. Cast Iron Pipe and Ductile Iron Pipe are normally coated with a Bituminous paint as a protection against corrosion. Pipe lining is quite common in cast iron and ductile iron pipe and is comparatively inexpensive. This increases the pipe smoothness thus reducing the pipe friction and, consequently, allowing more water to flow through the pipe. This innner lining also prevents tuberculation build-up on the inside of pipe. There are several methods of lining metallic pipe, but the most common is a cement lining process.

Asbestos cement pipe and plastic pipe are both smooth-walled pipes, with a lower friction value than cast iron pipe, and thus do not require the type of inner lining commonly used in the iron pipes.

HANDLING

The first thing that happens to pipe when it is delivered to a project site is it is unloaded. However, before the pipe is unloaded it should be checked to see if it is the proper size, class and that it is undamaged (i.e. no chips, cracks, etc.). In general it is best to use mechanical means to unload pipe as this protects it from damage. Care should be taken to prevent abuse and damage of the pipe no matter what method of unloading is used since damage unnoticed can result in having to re-lay part of the pipe line due to failure found only after installation (e.g. failure to pass leakage test).

The following are some suggested methods and things to watch out for when unloading pipe on the job.

Concrete Pipe

"Tailgate" smaller pipe sizes. Use a crane on the larger diameters.

Asbestos Cement Pipe

Pressure pipe larger than 300 mm I.D. and gravity pipe larger than 450 mm. I.D., should be unloaded by equipment. If using ropes and skids lower one pipe at a time making sure it does not roll free during any part of its travel.

Ductile Iron Pipe

Unload using equipment, make sure you don't knock mortar lining (if any) loose.

Plastic Pipe

Avoid severe impact, in particular at temperatures below - $10^{o}C$, and undue abrasion do not slide over truck bed. When using slings they should be rope or webbing not steel or chain.

STORAGE

If pipes are to be distributed along the trench keep the following in mind:

1. Lay or place pipe as near the trench as possible to avoid excess handling later.

2. If trench is open it is advisable to string pipe on the side away from excavated earth wherever possible so that pipe can be moved easily to the edge of trench for lowering into position.

3. If trench is not yet open find out to which side excavated earth will be thrown, then string out on the opposite side (leave room for excavator).

4. Place pipe so as to protect it from traffic and heavy equipment; also, safeguard it from the effects of any blasting that may be done.

5. Care should be taken that pipe does not roll into the trench.

However, if the pipe is to be stockpiled the following should be remembered.

1. Stockpiles should be built up on a flat base.

2. The bottom layer should be supported uniformly along the barrel of the pipe so that the bells do not touch the ground.

3. When stacking pipe, bells should project over the end of the barrels in alternate layers.

4. Keep various sizes and classes grouped. Put short lengths, fittings, adapters, etc. in separate piles where they will be readily available.

5. When stacking PVC pipe do not stack loose pipe over one metre high and protect from sunlight by covering with a tarpaulin or other opaque material. Be sure to allow for the circulation of air beneath the cover.

6. Pipe should be stacked in a manner so that it will not roll down a grade.

Gasket Storage

Store all rubber gaskets and lubricant at a central point and distribute as needed. Keep them clean, away from oil grease, excessive heat and electric motors which produce ozone. The best way is to leave them in their original cartons and stored in a cool, dry place.

JOINTING

The main objective when jointing a pipe is to obtain a watertight seal. This is true of both pressure and gravity-flow lines. In this section we will deal mainly with flexible joints for the most commonly used types of pipe.

Reinforced Concrete Pipe

The joint is basically a flexible rubber and steel joint composing a bell and spigot friction-type joint. The rubber gasket type joint is very efficient, and provides a flexible connnection which permits expansion, contraction, or settlement in the pipe line without affecting its water tightness. There are many different types of couplings on the market for jointing pressure pipes. Most of these are used for special applications only because of the cost involved, or for emergency repair work to pressure mains.

Asbestos Cement Pipe

The joints are basically friction-type couplings using a rubber gasket compressed between the spigot of the pipe and a recessed ring on the inner wall of the coupling.

Cast/Ductile Iron Pipe

The common types of joints in cast iron pipes are mechanical joint, tyton joint, lead yarn joint. The mechanical joints and the tyton joints use rubber gaskets as the sealant. The mechanical joint is based on the engineering principle of the stuffing box and comprises flange cast integral with the bell of the pipe. A rubber gasket fits into a recess in the bell socket and the metal gland is bolted to the bell flange, which compresses the gasket and seals the joints. The tyton is a simple push-on type of joint with only one component - a suitably shaped rubber gasket. This joint permits deflection in any direction of up to 5 degrees, or approximately 1 inch in lateral offset per foot run for pipe sizes up to 12 inches in diameter. In recent years the tyton joint has become a most popular type of joint because of its ease in installation.

Plastic Pipe

The joint used on PVC pipe is usually similar to the "Tyton" joint used on ductile iron pipe. The only installation difference is that rather than lubricating the rubber gasket, the spigot of the pipe is lubricated before homing the pipe to the reference mark. Other types are:

1. Solvent Welded joints with spigots welded to a sleeve-type coupling.

2. Solvent Welded joints with spigot welded into an extruded bell.

Considerations in Jointing

The following are important points to consider in jointing pipes.

1. The pipe should be lowered into the trench by using mechanical equipment in such a manner as to prevent damage to the pipe. Rolling, dropping or dumping into the trench shall not be allowed.

2. The pipe should be swabbed or brushed, wiped clean and dry and free from oil and grease before the pipe is placed in the trench.

3. During assembly every precaution must be taken to prevent foreign materials from entering the pipe. Trench waters shall be kept out of the pipe and the pipe end shall be kept closed all the time by means of a plug whenever work is not in progress.

4. Make sure that pipe manufacturers' instructions for jointing the pipe are followed closely for different specific joints and types of pipe.

5. After the pipe is assembled in the trench, the joints shall be checked to make sure that the ends abut each other in such a manner that there is no uneveness of any kind along the inside of the pipe and that the jointing material or gasket is properly and solidly in place.

6. Keep the pipe horizontal when jointing (use slings or cranes).

7. Use a bar or come-along when homing pipe. Never

use the bucket of a backhoe as it may break the pipe.

8. When using a trench box anchor pipe so they will not move when the box is pulled ahead.

APPENDIX A

REFERENCE STANDARDS

A.W.W.A. C-101 -	Standard for Thickness Design of Cast Iron Pipe with Tables of Pipe Thickness.
A.W.W.A. C-102 -	Standard for Cast Iron Pit Cast Pipe for Water or Other Liquids.
A.W.W.A. C-106 -	Standard for Cast Iron Pipe Centrifugally Cast in Metal Molds for Water or Other Liquids.
A.W.W.A. C-108 -	Standard for Cast Iron Centrifugally Cast in Sand Lined Molds for Water or Other Liquids.
A.W.W.A. H-371 -	Standard for Thickness Design of Ductile Iron Pipe.
A.W.W.A. C-151 -	Standard for Ductile Iron Pipe Centrifugally Cast in Metal Molds or Sand Lined Molds.
A.W.W.A. C-201 -	Standard for Fabricated Electrically Welded Steel Water Pipe.
A.W.W.A. C-202 -	Standard for Mill Type Steel Pipe.
A.W.W.A. C-300 -	Standard for Reinforced Concrete Water Pipe, Steel Cylinder Type not Prestressed.
A.W.W.A. C-301 -	Standard for Prestressed Concrete

Pressure Pipe Steel Cylinder Type for Water or Other Liquids.

A.W.W.A. C-302 -	Standard for Reinforced Concrete Water Pipe Non-cylinder Type not Prestressed.
A.W.W.A. C-400 -	Standard for Asbestos Cement Preesure Pipe.
A.W.W.A. H-2 -	Standard Practice for the Selection of Asbestos Cement Water Pipe.

SUBJECT:

WATER DISTRIBUTION
SYSTEM COMPONENTS

TOPIC: 8

Watermain Appurtenances

OBJECTIVES:

The trainee will be able to:-

1. Identify and state the function of various watermain appurtenances.

2. Install, operate and maintain a gate valve.

3. Install, operate and maintain a hydrant.

WATERMAIN APPURTENANCES

General

A trunk watermain or watermain system requires various aids to allow efficient operation or control, generally termed appurtenaces. These are discussed below.

VALVES

Control Valves

These are spaced to minimize the area that would be deprived of water service in the event of a line break or a planned or emergency shut-down.

Gate valves are generally used in distribution mains. It is common practice to install four valves at a four-way intersection and three valves at a three-way intersection. Valves would be spaced at a maximum distance of 150 m at other occasions but this will vary in accordance with the density of land use. These are discussed in greater detail later in the topic.

Butterfly valves are often used in trunk mains as they cause less pressure disturbance in opening or closing. These would be placed at zone changes, municipal boundaries or between major distribution main junctions. These are also used in distribution mains larger than 300 mm diameter.

The specifications should give the direction of valve opening which should be consistent with the bulk of valves presently in the system or as approved by the client. The size of operating nut or type of operator should also meet these requirements.

When a connection is required to an existing

system, often a tapping sleeve will be used. A pressure tap consists of a tapping sleeve which is braced around the pipe to be cut into and a gate valve which is attached to the sleeve to prevent the water from the pressurized pipe escaping after the connecting hole is cut in the existing pipe. Pressure taps are most common for small diameter connections and not used for very large connections as the tee must be reinforced if the circular structure of the pipe is excessively reduced by a large diameter tee connnection.

Air Relief Valves

A watermain can carry considerable amounts of air and water. This is not a serious problem in a system with many fire hydrants as these can be used to relieve air build-up in the system from time to time. Smaller mains may have a copper blow-off pipe attached to the pipe controlled by a gate valve.

Trunk watermains require air relief valves. These valves are generally designed to operate automatically, permitting bleeding of air from the main whenever necessary. Air build-up will take place at a high-point in the system, as the velocity in the main will be at its lowest thereby allowing the air to gather at this high point. This can be considerable if the high point is located a long way from the reservoir, if a gravity system, or from the pump, if a pressure system. If enough air collects without relief, a pressure block will form in the main severely disrupting supply.

In certain systems air valves can be installed which also act as vacuum valves. In this condition, the valve permits the flow of air into the line during draining of the line and the internal pressure reverts to atmospheric. This prevents a vacuum forming in the line and protects the system from collapse.

Drain Valves

Larger diameter watermains have drain valves installed at the lowest points of their alignment to permit draining of the main. The drain valves are gate valves generally placed on a tee to the side of the main, draining to a watercourse or other means of removal of the unwanted water.

Valve Chambers

These are generally provided for large valves which may have a handwheel for their operation or are electrically operated. The chambers may be poured-in-place or formed with precast sections. In either case, the chamber should be large enough to permit easy access to the valve both for operation or removal. Large valves may require couplings to be placed in the pipe beside them in the chamber to permit removal of the valve. (See Figures 8-1, 8-2, 8-3 at end of topic).

Valve Boxes and Stems

These are used for smaller valves where it is necessary to provide access to the operating nut. This access is provided by use of a valve box and stem. The stem is a hollow cylinder that fits over the operating nut. The valve box is attached to the top of the stem and provides access from the ground surface. The stem and box assembly should be adjustable to permit adjustment with respect to roadwork. (See figure 8-4).

GATE VALVES

Purpose

Standard gate valves with non-rising stems are used for line control. The stem passes through a stuffing box or packing gland into the casing of the valve, and when

the stem is rotated it lifts the gate mechanism which generally comprises a wedge and twin disc or gate that is wedged close against the parts of valve in the closed position. These valves normally have flange ends, hub ends, or mechanical joint ends. Valves of a size 24 in. or greater need some type of gearing to operate the opening and closing of the gates.

Installation

1. When valves are received they should be handled carefully to avoid distortion, breakage and damage to flanges and seats. Have valves in the closed position until time for installation. Protect stored valves from the elements if possible.

2. Before installation clean foreign material from piping.

3. Install valves in the line making sure that both pipe and valve are adequately supported so that line stresses are not transmitted to the valve body. Do not use a valve as a final joint to correct any error in piping alignment or spacing.

4. In the case of flange end valves, tighten flange bolts uniformly and in stages. Pull up bolts on diametrically opposite sides of the flange until all bolts are uniformly tight and the joint gasket has sufficient compression to prevent leakage at the test pressure.

5. In the case of screw end valves, make sure the pipe does not screw too far into the valve and damage the seat rings. Apply pipe compound to the male thread only. Do not force pipe into a screw end valve.

6. Certain valves, such as square bottom or automatic drip valves, are designed for one way flow. The

direction of flow is indicated by an arrow cast on the body.

7. Check for proper operating clearance when installing valves.

Operation:

1. Direction of opening is indicated by an arrow cast on the handwheel or wrench nut of the valve.

2. Operate gate valves from full closed to full open position and back before applying pressure.

3. Close gate valves slowly against pressure to avoid damage from surge or water hammer.

4. Valves installed on liquid service subject to freezing conditions should be protected to prevent trapping of liquid between discs, expansion on freezing and subsequent damage. The same is true of valves subject to considerable temperature increases, especially on volatile liquids. Trapped pressure should be vented back to the upstream side to prevent build-up of pressure in the valve bonnet due to high temperature expansion.

Maintenance:

1. Operate gate valves from full open to full close at regular intervals. The length of time between operations depends on the time of installation and the service conditions.

2. Keep the stem thread and packing lubricated. Hydraulic oil for the packing and graphite grease for the stem thread are suggested.

3. Check the packing for leakage at regular intervals. If leakage cannot be stopped by drawing down on the packing, the valve should be repacked.

4. On repacking a valve, be sure to check the valve service and obtain the proper packing. To obtain packing that will fit the stuffing box from the factory, forward the information cast on the side of the valve body and order the packing for the quantity of valves to be repacked.

5. To repack a valve, run the valve to the full open position and back seat the stem tightly against the bonnet. It will then be possible to repack under pressure.

6. Gate and seat surfaces may become damaged or scored in operation. These surfaces may be refaced in the field. Disassemble the valve and reface in a standard lathe, making sure the seat ring faces are square with the bonnet flange on the body.

<u>NOTE:</u> *2 and 3 above will refer to the maintenance of gate valves with standard packing. Where "O" ring packing is used, they can be disregarded. Damaged "O" rings can be replaced using the procedure outlined in items 4 and 5.*

<u>Spare Parts:</u>

Under most conditions the only spare parts needed for a gate valve would be stem packing and bonnet gasket. Under rigorous service stems, gates and seat rings should be carried as spare parts as well as stem packing and bonnet gaskets.

PIPE FITTINGS

The most common type of pipe fittings used in a water distribution system are the bends, tees, crosses and reducers. Details and dimensions for these fittings are obtainable from the various bound books produced by the pipe manufacturers or from the A.W.W.A. specifications.

Pipe couplings of various types are commonly used - more especially in the maintenance operations for quick repairs. Some of these types are as follows:

1. Standard Sleeve Straight Cast Couplings

   Used for connecting two plain-end pipes of same diameter together.

2. Transition Cast Couplings

   Used for connecting two plain end pipes of different outside diameters but same nominal size.

3. 360° All Round Pipe Repair Clamp

   Steel sleeve with rubber gasket lining for joining two plain ends of same diameter normally used to close circumferential break in watermain.

4. Victaulic Coupling

   A steel and rubber gasket-type coupling, generally used to join two spigot end pipes, with special victualic groove out in end of pipes; much less bulky and lighter in weight than standard sleeve couplings.

HYDRANTS

General

A hydrant is basically a control valve in the waterworks system which allows water to be made available above ground level in large quantities. Hydrants consist of a cast iron barrel with a bell or flange fitting at the bottom to connect to a branch from the watermain. At the bottom of the cast iron barrel there is a control valve of the gate or compression type, operated by a long valve stem, terminating in a nut at the top of the barrel. Water passes up the barrel on the opening of the valve at the base of the hydrant and passes to the fire hoses through two 2-1/2 in. hose outlets. (See Figure 8.5).

Fire protection manuals suggest that hydrants be located so that no building is more than 120 m from a hydrant. Hydrants are equipped with a shut-off valve between the hydrant and the main. This facilitates the maintenance and replacement of hydrants without disturbance to the flow in the main.

Hydrants must be installed in a way to ensure that they do not move or that joint separation is not caused by the water pressure. This is usually accomplished by the use of wooden or concrete thrust blocks at the base of the hydrant stand-pipe or by the use of hydrant anchor tees.

Installation:

1. When hydrants are received they should be handled carefully to avoid breakage and damage to flanges. Keep hydrants closed until they are installed. Protect stored hydrants from the elements if possible.

2. Before installation of hydrants clean piping and

base and drain ring of hydrant of any foreign material.

3. When the hydrant is set in a position and attached to the lateral, it is good practice to brace the side of the base opposite the inlet to oppose the stress due to pressure tending to force the hydrant off the end of the lateral.

4. It is recommended practice to install an auxiliary or secondary gate valve in the lateral between the hydrant and the main to permit inspection and repair of hydrant without shutting down mains.

5. When hydrant drainage is desired to prevent freezing, excavate around the hydrant drain ring and surround the base of the hydrant with crushed stone to a level about five inches above the lower barrel flange. The stone filled area should contain a volume of water at least twice that held by the hydrant barrel.

6. Both drainage stone and earth fill above the stone should be tamped to give firm support to the hydrant barrel.

7. Hydrant should be located to give minimum hazard to traffic. Place hydrant back from the curb line to prevent damage to or from overhanging vehicles. On main thoroughfares place hydrants far enough from intersections to avoid damage from accidents. Place hydrants so they are readily visible and accessible. It is suggested that hydrants be painted with reflective paint or marked with reflective tape to permit easy identification at night.

8. When first installed the hydrant should be operated from full closed to full open position and

back to make sure no obstructions are present.

9. After the hydrant is installed and the line, as well as the hydrant, have been hydrostatically tested, the hydrant should be flushed and then checked for proper drainage.

Operation:

The modern hydrant is designed to be opened and closed without the use of "cheaters". Excessive leverage may damage the hydrant, therefore:-

1. Check direction of opening as marked on the hydrant cover.

2. To OPEN turn the operating nut until the valve hits the stop in the opening direction. DO NOT FORCE THE HYDRANT IN THE OPENING DIRECTION BEYOND FULL OPEN as indicated by sudden resistance to turning. If water does not flow when the hydrant is open, it is probably due to a closed valve upstream from the hydrant.

3. To CLOSE turn the operating nut until the valve closes off the flow. It is NOT NECESSARY TO CLOSE this style of hydrant WITH GREAT FORCE. Once the flow has stopped loosen the operating nut in the opening direction to take the strain off the operating parts of the hydrant and to make it easier to open the hydrant when again needed.

4. Fire Hydrants are NOT a throttling device and, therefore, ARE to be OPERATED either in the FULLY OPEN or FULLY CLOSED POSITION.

Inspection:

1. It is recommended that hydrants be inspected twice

a year, spring and fall. After each use in extremely cold weather hydrants should be inspected.

2. Inspection should cover the following points:-

   a. External inspection - paint, caps, chains, etc.
   b. Valve leakage - aquaphone check.
   c. Hydrant, drain & nozzle leakage - pressure test of entire hydrant.
   d. Hydrant drainage.
   e. Operation from full close to full open and reclose.

<u>Maintenance</u>:

1. At time of inspection add #1 graphite grease or cup grease at the grease fitting in the top of the operating nut. Do not use excessive greasing pressure on the gun in order to prevent hard operation. Also grease nozzle cap threads with #1 graphite grease.

2. <u>Removal of Internal Parts</u>:

   a. Shut off water in line leading to hydrant.
   b. Open hydrant valve.
   c. Remove bolts and nuts from top flange.
   d. Take off domed cover.
   e. Remove operating head by continuing to turn in the open direction until the thread is turned out of the operating unit. Then carefully strip the head up over the threads.
   f. Place the seat wrench over the rod making sure the square hole in the seat wrench engages the rod square. Turn to LEFT or COUNTERCLOCKWISE to unscrew main valve and

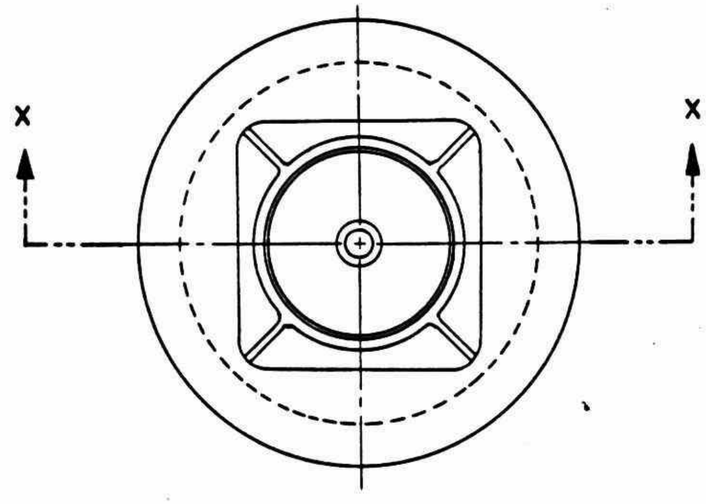
drain assembly from the main valve seat drain ring.

g. Remove seat wrench.

h. Lift out hydrant rod and all working parts for inspection or repair.

i. When a new valve ball leather or rubber is installed, it is necessary to install a new lead gasket between the valve ball bottom and the lock nuts to prevent leakage through the valve ball.

3. At time of inspection flush out the hydrant lead and hydrant itself. If necessary flush the drains by filling the hydrant and then open the main valve two turns to force water out of the drains under pressure. The drain valve is open during the first three turns of the operating nut.



VALVE SIZE	CHAMBER I.D.	"A"
4" to 12"	5'- 0"	6"
16"	6'- 0"	9"

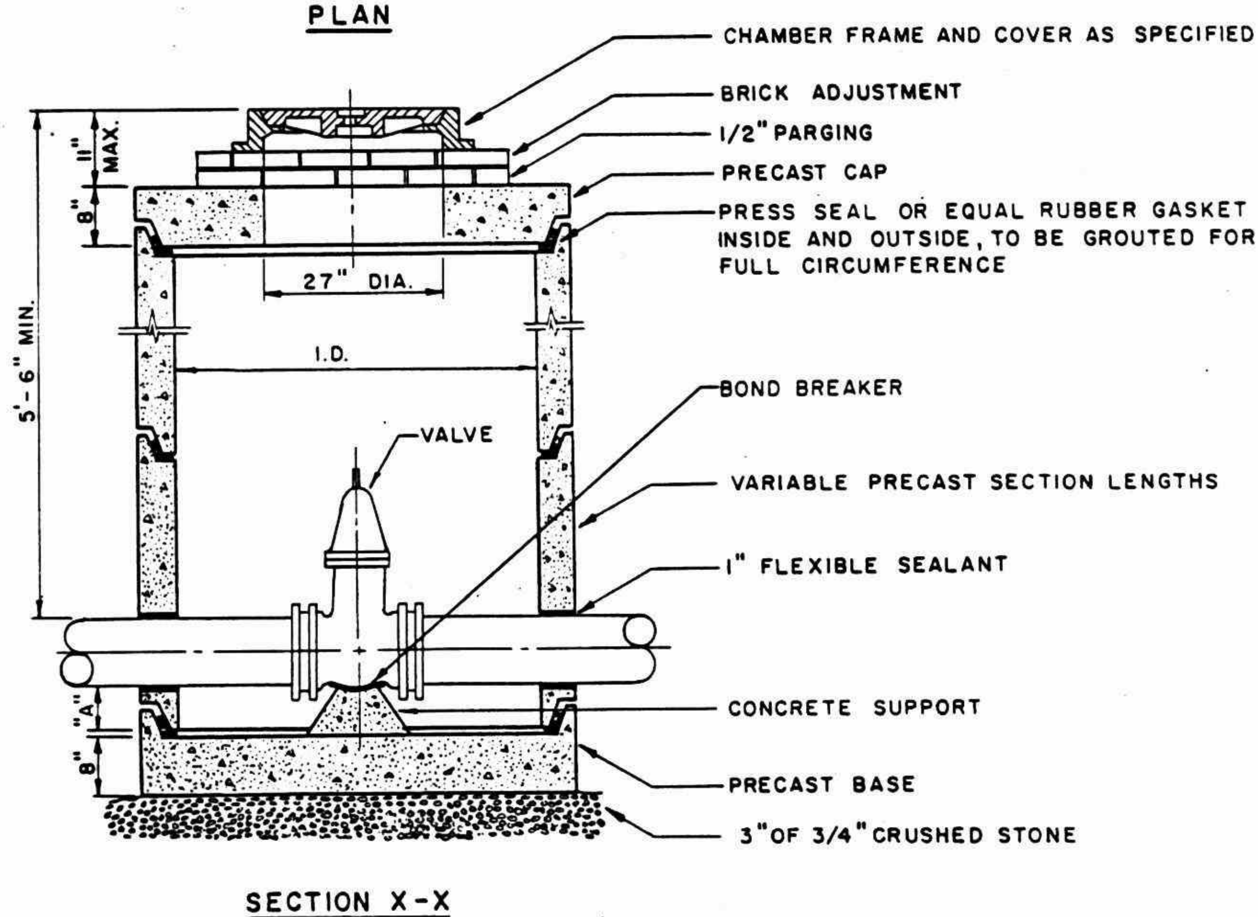


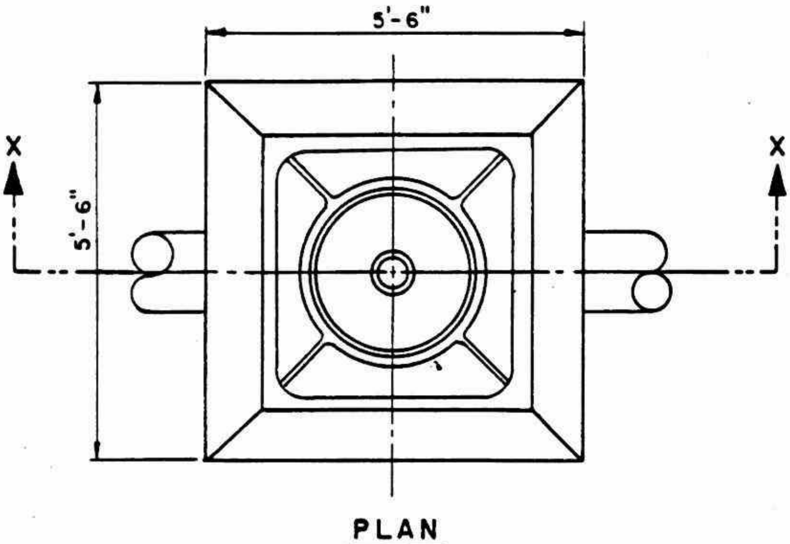
Figure 8-1

PRECAST VALVE CHAMBER

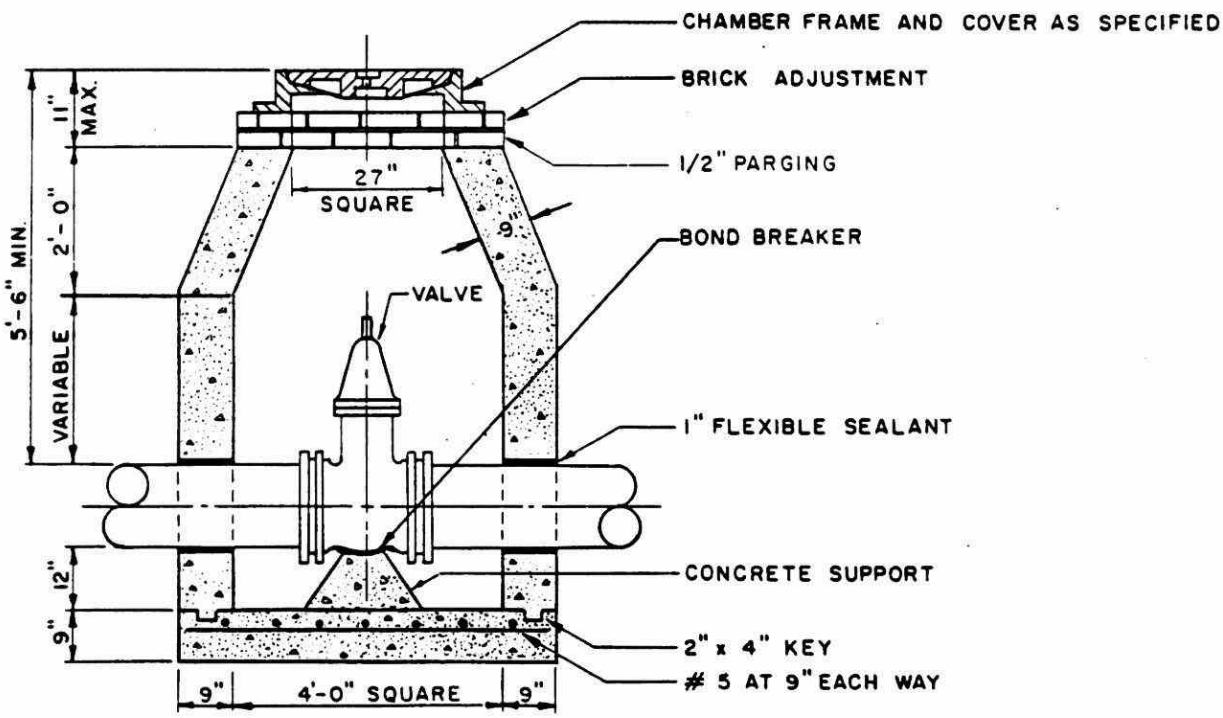
16" DIAMETER MAINS AND SMALLER

NOTES:

(1) MANUFACTURED TO A.S.T.M. C-478 SPECIFICATIONS.
(2) PARGING MIX ON ALL BRICKWORK TO BE 1:3 MORTAR MIX.
(3) ALL JOINTS AND LIFTING HOLES IN CHAMBER SECTIONS TO BE COMPLETELY FILLED WITH A 1:3 MORTAR MIX AND POINTED BEFORE BACKFILLING.



PLAN



SECTION X-X

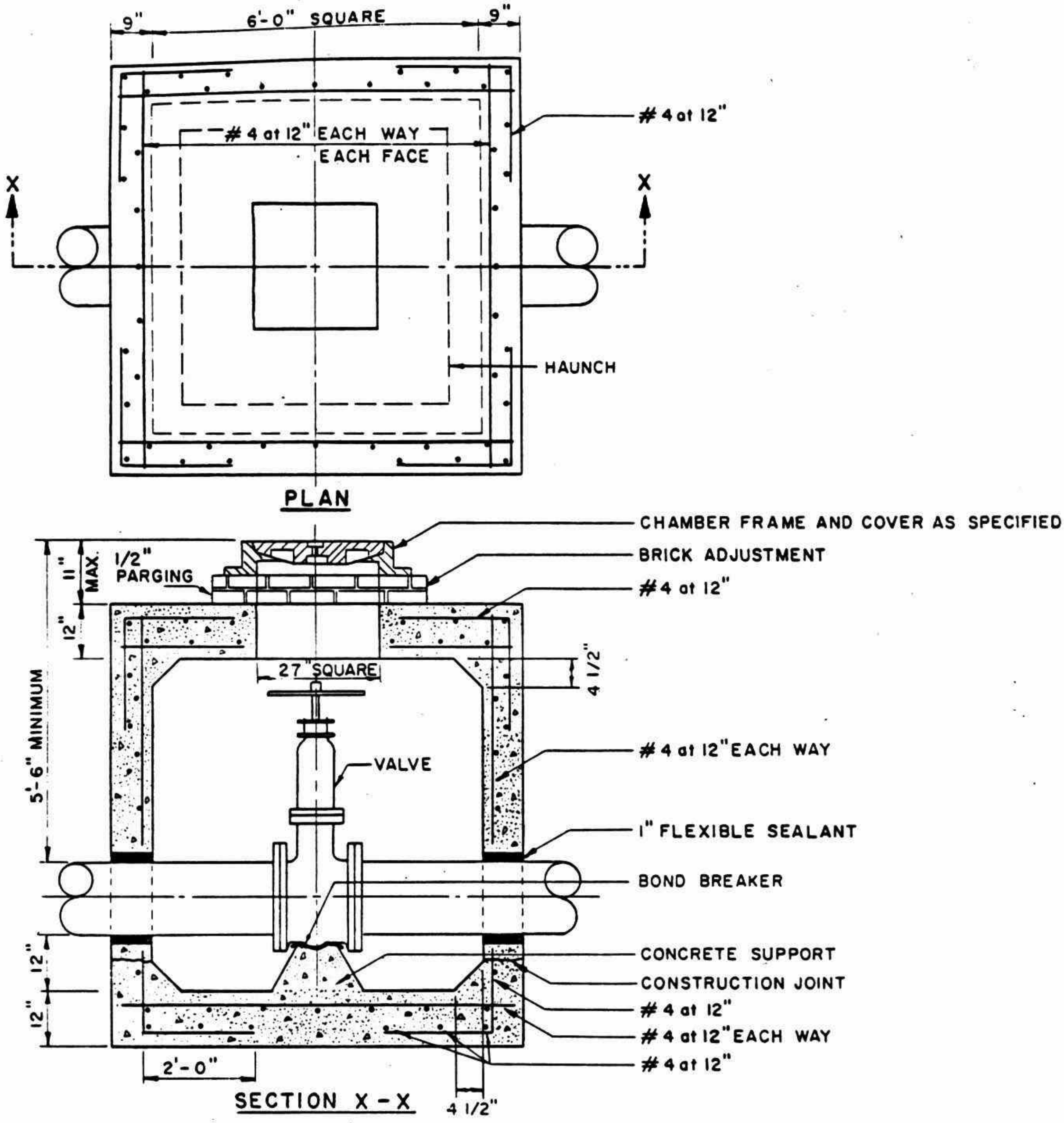
Figure 8-2

CAST IN PLACE VALVE CHAMBER

12" DIAMETER MAINS AND SMALLER

NOTES:

(1) ALL CONCRETE TO BE 3,000 P.S.I. AT 28 DAYS.
(2) MINIMUM COVER OVER REINFORCING TO BE 3".
(3) PARGING MIX ON ALL BRICKWORK TO BE 1:3 MORTAR MIX.



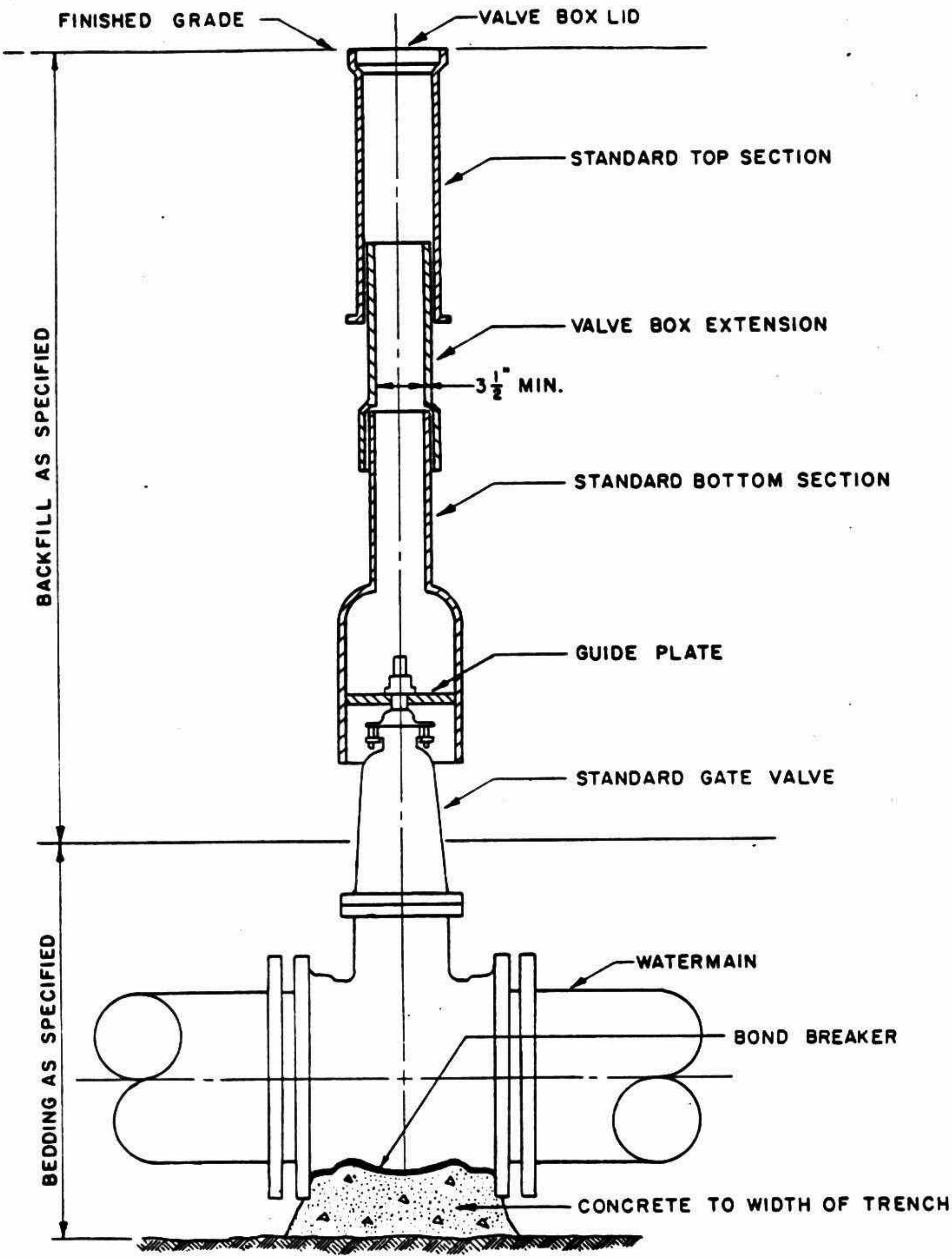
NOTES:

(1) ALL CONCRETE TO BE 3,000 P.S.I. AT 28 DAYS.
(2) MINIMUM COVER OVER REINFORCING TO BE 3".
(3) PARGING MIX ON ALL BRICKWORK TO BE 1:3 MORTAR MIX.

Figure 8-3

CAST IN PLACE VALVE CHAMBER

16" DIAMETER MAIN



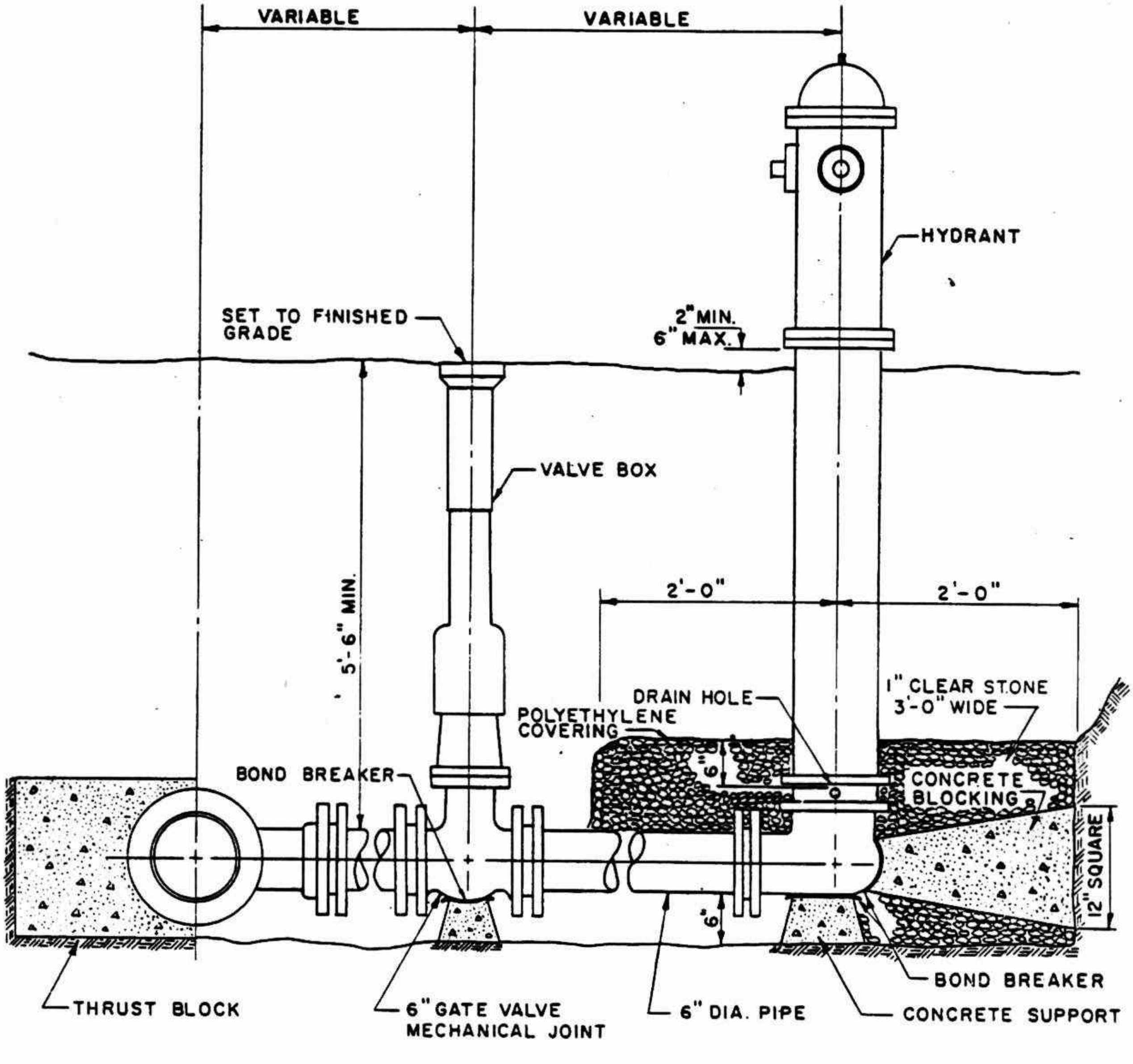
NOTES:

(1) VALVE BOX TO BE ADEQUATELY BRACED WHILE BACKFILLING AND MUST REMAIN PLUMB.
(2) VALVE BOX EXTENSION TO BE USED ONLY IF REQUIRED.
(3) BOND BREAKER TO BE USED BETWEEN CONCRETE AND VALVE.
(4) ALL CONCRETE TO BE 3,000 P.S.I. AT 28 DAYS.

Figure 8-4

VALVE BOX INSTALLATION

4" TO 12" DIA. WATERMAINS



NOTES:

(1) ALL CONCRETE TO BE 3,000 P.S.I. AT 28 DAYS.
(2) ALL CONCRETE TO BE AGAINST UNDISTURBED TRENCH WALL.
(3) BOND BREAKER TO BE USED BETWEEN CONCRETE AND FITTINGS.

Figure 8-5

HYDRANT INSTALLATION

SUBJECT:

WATER DISTRIBUTION SYSTEM OPERATIONS

TOPIC: 9

Service Connections and Sizing

OBJECTIVES:

The trainee will be able to:-

1. Define the term water service connection
2. Identify the components and details of a standard water service connection
3. Recall the minimum acceptable diameter of a water service
4. Recall the recommend depth of bury for service lives
5. Recall the procedure for installation of corporation main stops
6. Describe two (2) types of saddles
7. Recall the maintenance procedure for water meters
8. Calculate service and meter sizes

SERVICE CONNECTIONS AND SIZING

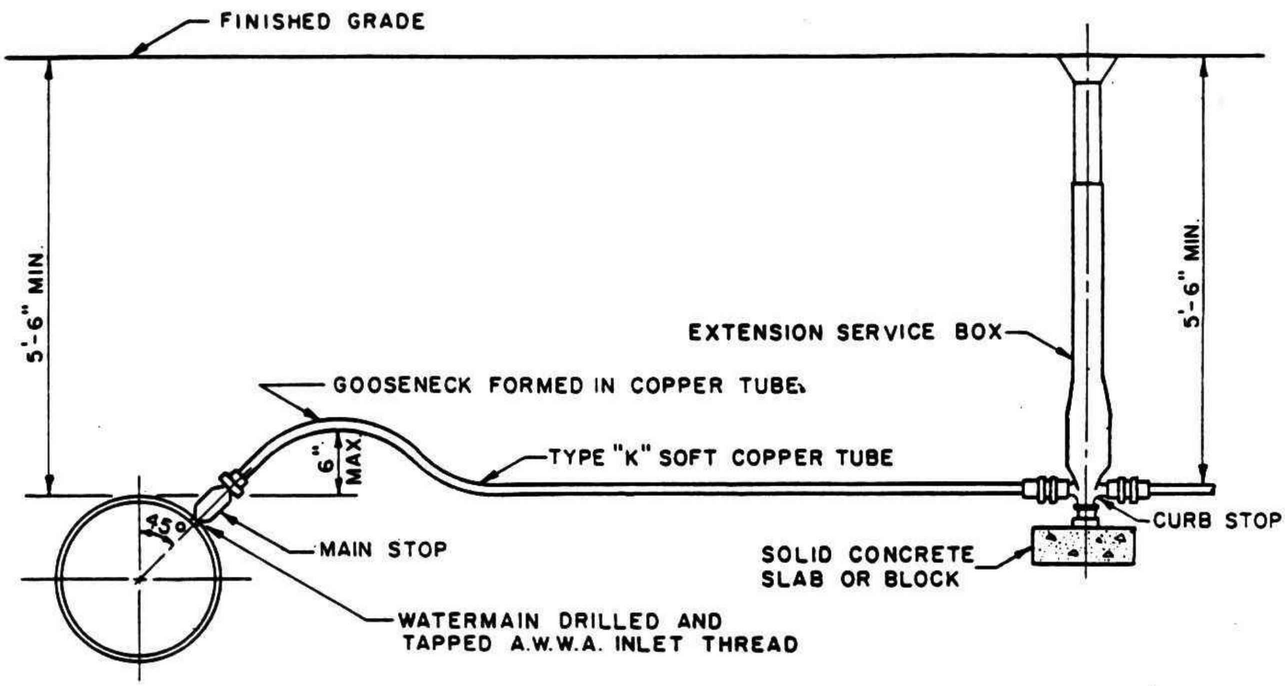
GENERAL

A water service connection is the piping from the watermain, which is normally within the road allowance, to the individual property. These connections are usually installed after the building has been designed, and the approximate water needs for flow and residual pressures have been determined. In a new subdivision, where the registered plan stipulates lot sizes and the agreement stipulates the type of buildings, these service connections can be installed at the same time as the watermain. See Figure 9.1.

WATER SERVICE SIZING

The minimum acceptable diameter of a water service is 3/4 in. This size is normally adequate for single family dwellings and small commercial establishments. Larger commercial and industrial complexes, of course, need larger connections for domestic use. Quite often, large diameter connections are also required for sprinkler, standpipes, or other fire control facilities. In these cases, the Owner of the building, his Consulting Engineers or Mechanical Contractors, will have to establish the size of water connections needed to provide adequate supply. For industries, it is impossible to standardize the size of services, but for some commercial buildings, such as apartment buildings, AWWA has prepared some guidelines.

In designing a service size for a building, where the required flow has been established, the residual pressure at that flow can be calculated if the pipe material and



NOTES:

(1) ANY JUNCTION MADE IN SERVICE PIPE BETWEEN MAIN STOP AND CURB STOP TO BE MADE WITH APPROVED COUPLINGS.

(2) ALL WATER SERVICES TO BE INSTALLED AT RIGHT ANGLES TO THE WATERMAIN UNLESS APPROVED OTHERWISE.

Figure 9.1

STANDARD WATER SERVICE CONNECTION DETAILS

FOR SIZES $\frac{3}{4}$" DIA. TO 2" DIA. INCLUSIVE

diameter, the length of service piping, the elevation at the flow, and the static pressure and elevation of the street supply are known. Consideration must also be given to fluctuations in street pressure, the pressure losses due to elbows, bends, and other fittings, and the pressure loss in the water meter at the required flow.

SERVICE LINES

Location

Service Lines are installed in the ground, below the frost line, and carry the water from the street main through the main stop, curb stop, and meter to the home, or commercial building.

Types

Down through the years, various types of piping have been used. The changes from one to another were brought about by their individual shortcomings. Wood mains were replaced by lead. Lead pipe was replaced by galvanized iron and steel pipe. Then brass service pipe was introduced but discarded for a number of reasons - high cost, disinfection and its inability to withstand stresses and strains. Copper pipe was then introduced. Today, more and more service lines are being laid in plastic. Copper is still the most predominant and lead pipe is still being used in certain localities for replacement purposes.

In small diameters, the most common pipe material at present is copper type "K", which is used from 3/4 in. dia. through 2 in. dia. service connections. In the sizes from 3/4 in. to 1¼ in. the tubing is usually purchased in 66 ft. rolls, while in the 1½ in. and 2 in. sizes it usually is available in 20 ft. lengths. Regulation 647 of the Ontario Water Resources Act (more commonly known as the Plumbing Code) has information pertaining to the type "K" tubing, its wall thickness, tolerances, etc.

In recent years, some municipalities have also installed plastic (in most cases polyethylene) tubing for service lines. The specifications for the polyethylene tube are outlined in the Plumbing Code under Section 29, subsection 1.(h).

In most municipalities, the next size up from 2 in. dia. service connection is the 4 in. size. In this size, as well as any larger sizes, usually Ductile Iron pipe is used, the same pipe as used for watermains themselves.

Depth of Bury

Depth of bury varies dependent upon location and how deeply the frost goes into the ground. More municipalities are using a deeper trench to overcome the possibility of frozen lines. In Ontario the depth of bury will vary from 4'6" to 7'6"; 6' and 6'6" are the more common depths. Bedding should conform to the practices used for watermains. (See Topic 6).

Service Fittings

CORPORATION BRASS FITTINGS are manufactured from a number of alloys known as Composition Bronze Castings. The standard specification for Composition Bronze is the ASTM Designation B62-63. It covers an alloy having a composition of copper, tin, lead and zinc used for component castings of valves, flanges and fittings. The common trade name of the alloy is 85-5-5-5 i.e., 85% copper, 5% each of tin, lead and zinc.

The specification also incorporates chemical, mechanical and hydrostatic test requirements. Under the heading "Workmanship and Finish", it reads in part as follows:

"The castings shall be free from injurious blow-holes, porosity, shrinkage defects, cracks or other injurious defects. They shall be smooth and well cleaned."

CORPORATION MAIN STOPS

A corporation main stop may be inserted into the main directly, or may be inserted into a saddle already mounted on the main itself. They may be installed under pressure or as a dry tap installation. These stops are also referred to as Main Stops, Corporation Cocks or Corporation Stops. It consists of a body, with an inlet and outlet and a key which is held in the body by a nut and washer to open and close the valve.

Installation

It is recommended that when installing main stops they be inserted at 45° angle with the service pipe looped to allow for ground settling, etc. This is applicable to all service lines except plastic. With a plastic service line, it is recommended that the main stop be inserted as close to the horizontal as possible.

Inlet End

The inlet end of the stop can be equipped with the AWWA thread, Iron Pipe thread or Wood Main thread. 90% of all main stops used have the AWWA thread. Wood Main stops have almost become passe.

The AWWA thread provides a steeper taper to give added strength near the stop body: a tighter joint is obtained and the increased taper lessens the tendency to split the watermain. The AWWA thread, (Figure 9.2(a) adopted by the AWWA in 1948 is also known as Mueller thread,

corporation cock (CC) thread or corporation stop (CS) thread.

In the days preceding the production of cast iron mains, wood mains were used. A few are still in use. A Wood Main stop was produced and is still available. The inlet thread is longer than it is on the regular main stop and therefore provides more threads to turn into the main. The water in the main caused the main stop to swell and helped make it a leakproof connection.

Listed below is a table showing the recommended minimum size of cast iron main for each size of tapping for service connections. If the main size is too small to provide the recommended number of full threads for the size of main stop, then a saddle should be used.

RECOMMENDED MINIMUM SIZE OF CAST IRON MAIN FOR EACH SIZE OF TAPPING FOR SERVICE CONNECTIONS

Size of Tapping	*1/2"*	*5/8"*	*3/4"*	*1"*	*1 1/4"*	*1 1/2"*	*2"*	*2 1/2"*
Smallest Size of Main	*3"*	*3"*	*3"*	*4"*	*6"*	*6"*	*8"*	*10"*
Approximate Number of Full Threads..	*5*	*4 3/4*	*4 1/2*	*4 1/2*	*4 1/4*	*4*	*4*	*4*

Key and Body Assembly

The body of the main stop has a brass plug known as the key inserted into it. The key is tapered, with a round opening through which the water flows and which permits drilling through the main stop to open the main. A 90° turn opens or closes the stop and controls the water flow from the main. The key is lapped to the body at time of production and secured through the body by means of a brass nut and washer. The nut is staked to swell the threads to the key so that it will not loosen.

Outlet End

The outlet end of the main stop has been adapted to meet the demands of the many different types of service lines. Included are:-

FIP
MIP
Increasing MIP
Lead Flange
Copper Flare
Copper Flare with Electrical Connection
Compression Connection for Copper Tube Size and
    Plastic Tubing with same OD as Type K Copper
Compression for IP Size Plastic Tubing
Insta-title Connection for Copper Tube Size Plastic
    with same OD as Type K Copper
Insta-title Connection for IP Size Plastic Tubing

Copper Flare is still widely used although fittings with compression ends are definitely taking over.

Copper Service Pipe Connections

The connection shown in Figure 9.2(b) was adopted by AWWA. The convex surface in the flared nut opposes the convex surface on the body giving a line contact initially and permitting the joint to be easily made. The convex surfaces do not compress the end of the flange, thus giving the joint greater resistance to pulling out. This type of connection is found on main stops, curb stops, couplings and adapters using a copper flanged nut.

Lead Flange Connection

The connection shown in Figure 9.2(c) was adopted by AWWA for extra strong lead pipe and is also available for double extra strong lead pipe. The knurled flare on the

FIGURE 9.2 CORPORATION STOPS

Figure 9.2(a)
AWWA Thread

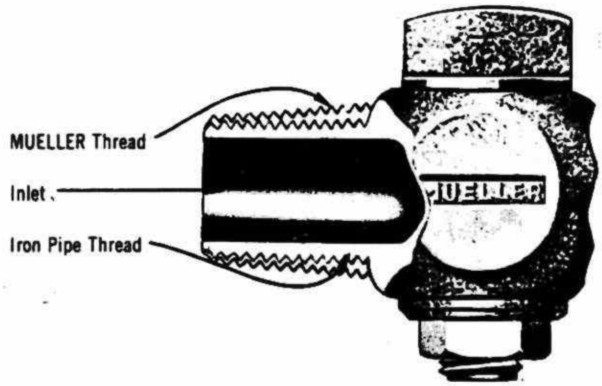


Figure 9.2(b)
Copper Service
Pipe Connection

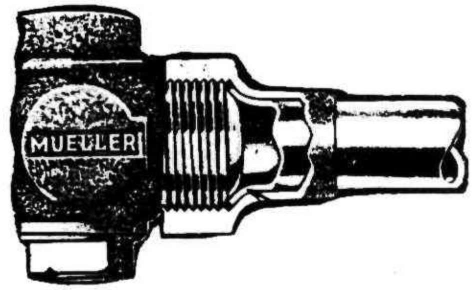


Figure 9.2(c)
Lead Flange
Connection

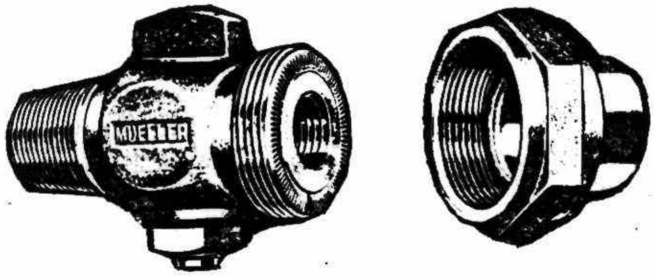
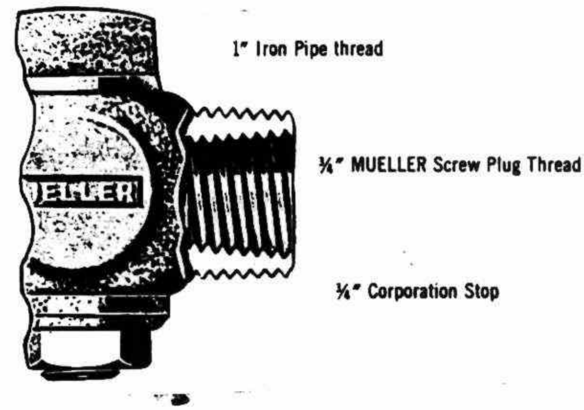


Figure 9.2(d)
Screw Plug
Thread

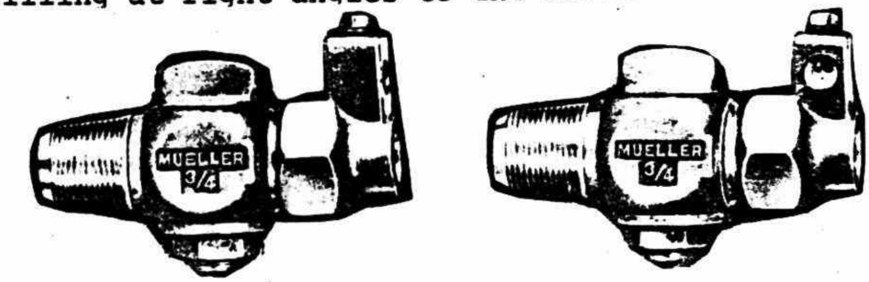


body of the main stop holds the pipe in a leak proof non-loosening joint.

Screw Plug Thread

This screw plug thread (Figure 9-2(d) is a female thread on the outlet end of a main stop. On the same main stop, outlet end, is a male IP thread identified as and described as Increasing IP thread.

In Figure 9.3 below two types of electrical tailpieces are shown. Figure 9.3(a) has a 7/16" drilling running parallel to the service. The other has the same drilling at right angles to the service line.



(a) (b)

Figure 9-3 COPPER FLARE WITH ELECTRICAL CONNECTION

Flaring

A flanging tool is used to flare the end of copper tubing to make a connection with service fittings. The tool is oiled and inserted in the pipe. A few blows of the hammer will flange the pipe until it engages with the recess in the tool.

Compression Connections

Corporation Brass Fittings with compression ends made their appearance on the market a number of years ago. Some of the features found in any compression fitting are:

1. Ability to resist pull out.
2. Speed of installation.
3. Conductivity - retention of metal to metal contact.
4. Type and style of material used for the gripper band - to improve pull-out capability.
5. Use of stainless steel liners with plastic lines.

Insta-Tite Connections

The Insta-tite Fitting is the newest type of connection made available to the water industry. The fittings are for use with Polyethylene pipe or tubing having an OD the same size as Type K copper tube or IP size. Fittings are for 3/4" and 1" service lines.

The installation procedure is quick and simple. The tubing is cut squarely, and the end is bevelled with a bevelling tool. It is then stabbed into the end of the Insta-tite fitting through a plastic "one-way" grip ring securely gripping the pipe to prevent pull-out. A resilient 0 ring provides a leak-tight seal at all pressures through the maximum rating of the PE pipe or tubing.

With Insta-tite fittings you can convert or replace flared copper tubing or iron pipe without removing the existing fitting. You merely remove the end and attach the Instatite end.

Shipping Procedure

Main stops are shipped with the valve in the closed position. This is done to prevent a stop being inserted into a main (open position) and the machine being removed with full water pressure flowing through the corporation stop.

Main stops that have a machine mounted on them to drill through the stop should be opened before drilling commences. Care should be taken to ensure the proper maximum drill size is used when drilling through the stop. Consult the manufacturer's catalogue to determine the proper drill size.

SADDLES

There are several different types and styles of saddles in use today. Two examples are the heavy galvanized malleable iron body type and the bronze saddles.

Malleable Iron Saddles

Saddles with the malleable iron bodies are available with both single and double straps. The nuts threaded on the ends of these straps are of rolled steel and like the threads on the straps are cadmium plated. Double strap clamps are recommended for 1 1/4, 1 1/2, and 2" tapping when used with higher pressures. Tappings range from 1/2 through 2" on most pipe sizes, in both single and double strapping. The heavy boss is tapped with a full thread for either the AWWA or IP thread.

Saddles are available from 1" through 12" on steel pipe and 1 1/4" through 12" on cast iron. Once the main is installed on the saddle you can mount the E4 or D5 drilling machine with the proper drill size and proceed to cut the main.

Bronze Saddles

Bronze saddles are designed for wrapping around IP size PVC main 2" through 12". These saddles utilize an O ring cemented in the clamp body for sealing. This saddle will take a 3/4 or 1" corporation main stop in either AWWA threads or IP threads. The saddle is secured to the main by

tightening the two bronze silicone screws with a screw-driver. When the main stop is installed, drill the main with a PL2 or E4 drilling machine, using the proper drill size.

CURB STOPS

Curb stops are known as plug or ball valves. Both types are termed as "easy turn" valves compared to an inverted key stop. The plug valves are equipped with 0 rings for sealing and ease of turning. The direction of water flow is indicated by an arrow on the side of the body. A 90^{o} turn is provided which aligns the drain orifice on the stop and drain models. A liner is used to provide a non pressure drop between the ports in the plug. As with other curb stops the top of the key is drilled to receive a cotter pin. A lever handle can be provided for inplant installation for hand operation. See Figure 9-4 for illustrations.

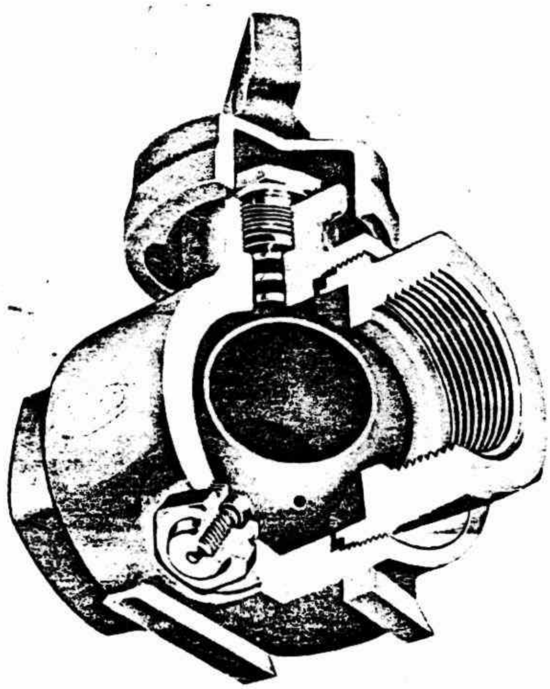
Location

The name "curb stop" probably originated from the point of installation at or near the curb, presumably to make it easier for locating when necessary. Today they may still be installed near the curb, the boulevard, in the sidewalk or on the lawn away from the street-side of the sidewalk, with the location identified by the cast top of the service box if it is exposed at ground level.

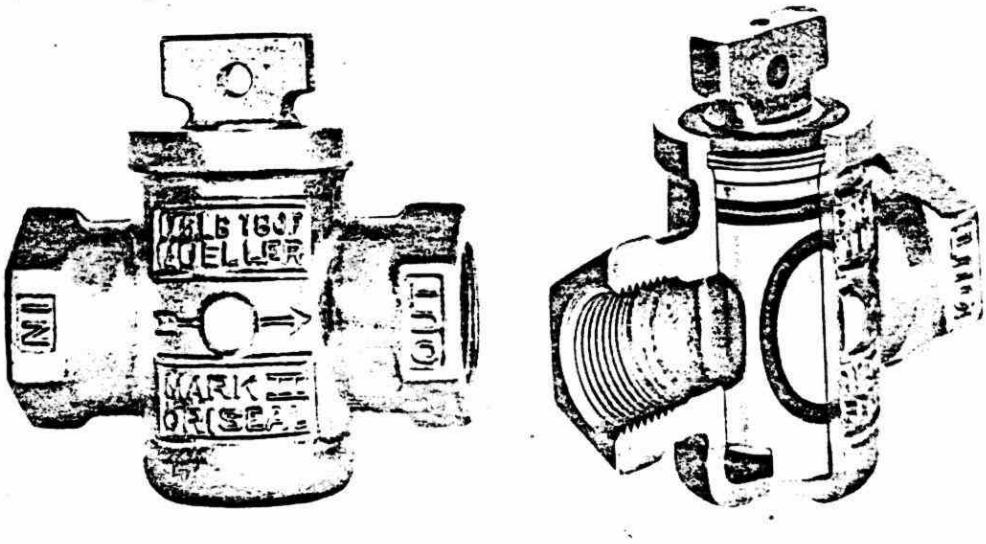
Types of Keys

The earlier style of curb stop was identified as a solid tee head pattern. The key was secured to the valve body by means of a nut and washer which when drawn tight, also created the seal. This style is still available, although in limited types. The inverted key, with the round way for the waterflow has been widely used for a number of

FIGURE 9.4 CURB STOP VALVES

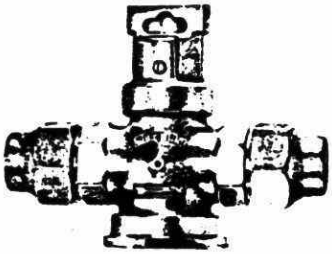


BALL VALVE



ORISEAL CURB VALVE

FIGURE 9.5 CURB STOPS - KEYS AND DRAINS

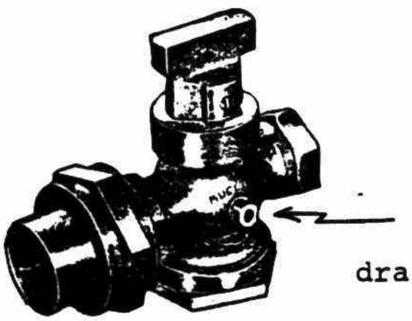


INVERTED KEY CURB STOP AND DRAIN

(Copper flare inlet and outlet)

SOLID TEE HEAD CURB STOP

(Iron pipe to iron pipe)



drain

INVERTED KEY STOP AND DRAIN

(Compression to Compression)

years. Actually the roundway is more oval than round. See Figure 9-5.

Types of Ends

Like the main stop, the curb stops are available with numerous ends on both the inlet and the outlet sides.

FIP	X FIP
Lead Flange	X FIP
Lead Flange	X Lead Flange
Copper Flare	X Copper Flare
Copper Flare	X FIP
Compression	X FIP
Compression	X Compression
Compression	X Copper Flare

Stops & Drains

All of the above types are available with a stop and drain. On the side of the curb is a "boss" which when drilled at the factory, provides the drain feature. Drilling of this boss in the field is not recommended. A burr will be left on the inside of the body which could cut into the body of the key, score it and cause a leak. The drain permits the line to drain pressure dry when the valve is closed. It will not necessarily drain water dry.

Tailpieces

Tailpieces for curb stop and drains are similar to those made available with the corporation main stop.

Direction of Flow

On the side of the curb stop body is an arrow indicating the direction of the flow of water. It is important to ensure installation with the arrow pointing in

the direction of the water flow, otherwise the valve will be open when the key is in the closed position and in the case of valves with 0 rings, the 0 ring can be cut when the valve is turned and a permanent leak will result.

Key & Body Assembly

Like the main stop, the curb stop has a brass plug known as the key inserted in its body. The key is turned through 90° to open or close the curb stop. The key is lapped to the body when in production. The Tee head portion of the key is drilled to allow for insertion of a brass cotter pin in connecting it to the service rod.

On the inlet side of the body is a waterway which allows water to run to the bottom of the stop and by filling the inside of the cover, exerts upward pressure on the inverted key to help seal. This cover is screwed to the bottom of the body and has a gasket within it for sealing purposes.

Shipping Procedures

Curb stops are shipped with the key in the OPEN position. This prevents water from remaining in the stop after testing which could freeze causing body fractures before installation.

COUPLINGS AND ADAPTERS

Couplings and adapters are available to meet the requirements of the industry with ends similar to those provided for the curb stops.

Lead	X FIP
Lead	X MIP
Lead	X Lead
Copper Flare	X FIP

Copper Flare	X MIP
Copper Flare	X Lead Flange
Copper Flare	X Copper Flare
Compression	X FIP
Compression	X MIP
Compression	X Compression
Compression	X Copper Flare

BRANCH CONNECTIONS

Branch connections have been widely used to service cul de sacs, townhouse and condominium developments. These connections are provided in 2, 3, and 4 branches. The maximum outlet size on a 4 branch is 1": the maximum inlet size is 2".

In earlier days, branch connections were used in the reverse procedure to what we know today. Several small main stops were installed in a main relatively close together and connected to a branch connection to service a larger water line of 1 1/2" or 2".

ANGLE METER STOPS

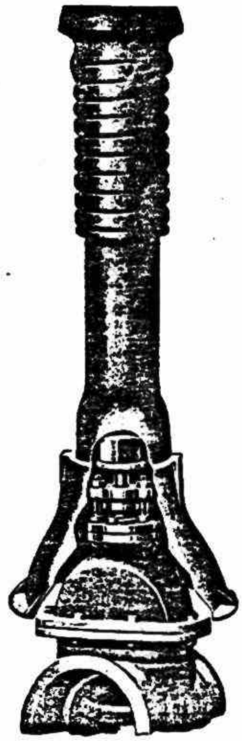
Angle meter stops, installed in the building before the meter, are avilable with 3/4" and 1" compression connections. The outlet is furnished with a meter sized nut to connect directly to the meter. The nut is a swivel nut with a meter spud thread and is drilled for a wire seal. A hand controlled shut-off is provided which turns through 90°.

BOXES

Types

There are two basic types of boxes used in the

FIGURE 9.6 SERVICE BOX AND KEYS



Valve Box and Valve

Shut off Key

Repair Lid Key

Extension Type
Service Box Rod

Repair Lid

Ribbed Lid

Flat Lid

Water Industry, the extended type service box and the valve box, (Figure 9-6).

Installation

As the name implies, the service box is located and installed above the curb stop. The valve box is mounted over the gate valves near the hydrant installation.

Components

Six components make up a service box; the base, standpipe, lid, plug, rod and lock ring.

Sizing

Most service boxes used have a 1" Upper Section or Standpipe which telescopes a maximum of 12". Some are available that telescope 24". The base is designed so that the arch will fit over a 1/2", 5/8", 3/4", and 1" curb stop. Properly installed over the curb box, the base helps keep dirt from getting in around the top of the curb stop and making it difficult to operate the opening and closing of the valve.

For curb stops sized 1 1/4", 1 1/2", or 2", a box with a 1" upper section, may be used but with a larger base which provides a wider and higher arch to go over the valve.

Lids & Plugs

Two lids are available. The cast lid is ribbed and is equipped with a brass plug which when removed provides access to the shut-off rod. The second lid is flat and intended for sidewalk installation. A brass thread bushing is provided to stop rust seizing the lid and hampering its removal. To activate the rod it is necessary to remove the lid by unscrewing it from the standpipe.

The brass plug has a cast worm thread for easier removal from the lid. The plug is standard with pentagon sides. A few municipalities use a special hexagon sided plug.

If there is a preference for a box with a 2" upper section, these are available for curb stops 1/2" through 2". The standpipe telescopes 9" and a flat lid is supplied with a large plug.

Box length

The length of service box is determined by the depth of bury for the particular area, taking into consideration soil and rock conditions, depth of frost penetration. Boxes with a maximum extension from 2'6" through 12' in 6" increments are available.

Rod Length

Standard lengths of rods are supplied with a box corresponding to its depth of bury. The rods are usually up to 24" shorter than the maximum depth of bury of the box. Many municipalities have varied this to suit their own requirements and take a shorter rod.

Rod Construction

Small service box rods are made of 9/16" round steel, heated and forged to kink the upper end for rod alignment to provide easier insertion of the shutoff key with the top of the rod. On the bottom end of the rod is welded a "U" shaped steel clip with two holes drilled to take a brass cotter pin. The cotter pin holds the rod in place over the drilled key on the curb stop. A large 3/4" round steel rod forged and with malleable iron clips is provided to turn the key on large curb stops and valves.

WATER METERS

It has been said many times that the water meter is the cash register of the water company. As true as this statement may be, it should also be realized that it also serves to ensure that the consumer is only paying for that amount of water he uses. It is the responsibility of the receiver of water revenues to scrutinize the accounts to detect any apparent major variations in water bills. This having been done and a major variation detected, the meter is examined and, if necessary, repairs carried out either in the field or in the meter repair shop. A regular meter rehabilitation program is vital to accurate and equitable meter billings.

When meters are brought into the shop, a complete overhaul should be performed. The cases and measuring chambers of bronze meters should be cleaned by acid or by sand-blasting or a combination of both. The cases of castiron body meters are most effectively cleaned manually. A careful examination of all parts should be made before re-assembling the meter to ensure that any defective parts requiring replacement, but only those parts, are replaced.

Where corrosive water is a problem, protection to bronze parts, especially chambers, can be afforded by the application of a low viscosity high-film strength oil. The interior of cast iron meters can be protected by a high-molecular weight epoxy resin.

After the meters have been re-assembled they should be tested and recalibrated according to A.W.W.A. specifications.

In a recurring meter maintenance program, the proper period of time at which a meter should be overhauled is that time when the loss of revenue incurred if the meter is not overhauled equals the cost of meter repair and

maintenance. Repairing a meter too soon is as uneconomical as leaving an under-registering meter too long in service. Unfortunately, the optimum interval for overhaul of all meters applicable to all areas cannot be achieved because of such variables as prevailing water rates, the corrosive effect of the water, the wear-out rate of different types and makes of meters, prevailing wage rates and types of water usage in individual installations. Wear in a water meter has its greatest effect on accuracy in the low rates of flow. To properly gauge the time for overhaul, the characteristics of water usage on each installation should be known.

The flow in gallons per minute in the average home has been estimated as follows:

Flow rate - G.P.M.	Per cent of daily demand
10 - 12	11
4 - 6	47
2	22
1	10
1/2	5
1/4	5

It will be observed that a substantial percentage of water is drawn at the lower rates of flow. But the same meter may be used on larger than average homes or commercial or industrial installations where flow rate characteristics and percentage of revenue lost due to inaccurate meters are entirely different.

The variables involved make it impossible to establish a meter maintenance cycle that is proper for each installation. A general all inclusive schedule must be adopted, and, as a start of any program, the cycle as laid down by the A.W.W.A. should be adopted.

That cycle is as follows:-

Meter Size	Interval - Years
5/8	10
3/4	8
1	6
1-1/2	4
2	4
3	3
4	2
6	1

Maintenance costs money and in the case of distribution systems it can be a large sum. Obviously there is no substitute for good materials and sound engineering and construction practices.

APPENDIX A

SIZING OF WATER SERVICES & METERS

INTRODUCTION

The purpose of this topic is to provide the fundamentals for selecting service pipe and meters to ensure an adequate water supply to each consumer. It deals with smaller water services as a logical starting point. The procedure for selecting the pipe and meter size is to determine the peak flow requirements of the service and then calculate the losses of selected pipe and meters to determine the best combination for the service.

The same principles apply for larger, high flow services with the difference of assessing the effect of the high flow on the distribution system and the pressure available at the main. Fire services are beyond the scope of this paper as it is a specialized field to determine flow requirements.

The AWWA Manual on Sizing Water Services and Meters is a good reference book and should be referred to for additional information.

ESTIMATING THE PEAK DEMAND

The peak demand of a customer could involve 3 categories, domestic use, lawn watering and continuous demand (cooling water or similar use). Experience with the different types of consumers will be beneficial in determining their flow requirements.

Domestic Use

The domestic demand involves the use of plumbing fixtures and is normally calculated using the fixture value system. Each fixture was given an arbitrary value based on the number of gallons per minute used when the pressure at the outlet of the meter was 35 PSI, with only this one fixture in use. As an example, (Fig. 1), a washing machine with ½" connection obtained a flow rate of 5 gpm, so a value of 5 was assigned to this item. Fig. 2 includes the values for the common fixtures in use and therefore it is a simple procedure to multiply the number of each fixture in the structure times the assigned value to obtain the total fixture units.

The total fixture units are converted to estimated peak flows in g.p.m. by the use of Fig. 3 or Fig. 4. These graphs were developed by numerous field tests for each type of consumer, relating fixture units to demand flows.

Lawn Watering

The flow demand for lawn watering is very difficult to assess and will depend on conditions at each site and local rainfall trends. The plumbing layout, number of hose outlets and consultation with the owner or architect are the best means of estimating this flow requirement.

Continuous Demand

Continuous demand would include any water cooled equipment, compressors etc. which have fixed consumption rates when in operation. The owner or architect should supply information on these requirements.

Peak Demand

The peak demand is the sum of the domestic use, lawn watering and continuous demand. In some cases, future expansion of the structure will need evaluating and the pipe

sizing should be based on this projection. The meter should be sized for present day use with the provision for changing to a larger size with a minimum of pipe and valve changes.

The following is an estimate of probable domestic demand for a 160 unit apartment with the pressure at Meter Outlet 35 PSI.

Fixture		Factor		Fixture Value
205 Tank Water Closets	X	3	=	615
259 Lavatories-3/8"	X	2	=	518
138 Dishwashers - 1/2"	X	4	=	552
10 Washing Machines 1/2"	X	5	=	50
165 Kitchen Sinks 1/2"	X	3	=	495
162 Bathtubs	X	8	=	1,296
			Total	3,526

Total Fixture Value 3,526.

From Fig. 4 probable demand = 80 g.p.m.

Note: The above does not include any allowance for lawn watering.

SIZING SERVICE PIPES & METERS

Once the design flow rate is determined it is a matter of applying some basic hydraulic principles to determine pipe and meter sizes to supply the demand with an adequate residual pressure at the meter outlet. Each requirement for this calculation is explained in the following paragraphs.

Main Pressure

The main pressure can be determined by the use of

pressure gauges on the distribution system. A reduction of the pressure should be estimated for the additional losses in the system on the maximum consumption day. The water purveyor should be familar with distribution system pressure.

Elevation Correction

A pressure correction is required for any major elevation difference between the main and the meter location. The pressure varies by .43 PSI for each foot of elevation difference. The pressure would reduce at the meter when the elevation is higher than the main and increase when the elevation is lower.

Friction Losses

Friction losses occur in all pipes and fittings, and tables are vailable to determine the pressure loss for various rates and types of pipe. The friction loss table for 1/2" to 2" copper pipe is attached as Figure 5.

The various fittings have been examined as to friction loss and how that relates to equivalent length of straight pipe. An examination of Fig. 6 indicates that a 2" corporation stop is equal to 8.4 ft. of 2" pipe. Figure 7 provides the necessary information for 5/8" to 2" displacement type water meters. The table includes peak flow rating, design flow range, continuous flow rating and loss in P.S.I. at various flows.

TYPICAL SERVICE CALCULATIONS

Data: Flow - 80 U.S. Gals/Min.

Main pressure - 65 PSI (est. for peak day)

Meter is 10 ft. above main.

Service length - 120 ft.

Fittings used - main stop, curb stop, gate valve & 3 short elbows.

Pressure required at meter outlet - 35 PSI.

Check out 2" copper service with 1 1/2" meters.

Meter loss - - - - - - - - - - - - - - - - - - - 9 PSI

Fittings - Main stop - 8.4 ft.

Curb stop - 4.8

Gate valve - 1.2

3 short elbows -16.5

Equivalent length of straight pipe 30.9

Pipe 120 ft.

Say 151 ft.

Pipe & Fittings Loss

$$\frac{151}{100} \times 7 \text{ PSI} = 10.5$$ Say ----------------11 PSI

Elevation correction = 10X.43 PSI

= 4.3 PSI Say --------------------- 5 PSI

Total Loss ------------------------------25 PSI

Residual Pressure at Meter Outlet = 65 - 25 = 40 P.S.I.

- NOTE: 40 P.S.I. Residual is adequate.

Trial calculations for various combinations is the best method of becoming familiar with each phase of service and meter sizing.

FIGURE NO. 1

PLUMBING FIXTURE VALUE

FIXTURE TYPE	FIXTURE VALUE BASED ON 35 PSI AT METER OUTLET
BATHTUB	8
COMBINATION SINK AND TRAY	3
KITCHEN SINK: 1/2" CONNECTION	3
3/4" CONNECTION	7
LAVATORY: 3/8" CONNECTION	2
1/2" CONNECTION	4
LAUNDRY TRAY: 1/2" CONNECTION	3
3/4" CONNECTION	7
SHOWER HEAD (SHOWER ONLY)	4
SERVICE SINK: 1/2" CONNECTION	3
3/4" CONNECTION	7
URINAL: PEDESTAL FLUSH VALVE	35
WALL OR STALL	12
TROUGH (2' UNIT)	2
WASH SINK (EACH SET OF FAUCETS)	4
WATER CLOSET: FLUSH VALVE	35
TANK TYPE	3
DISHWASHER: 1/2" CONNECTION	4
3/4" CONNECTION	10
WASHING MACHINE: 1/2" CONNECTION	5
3/4" CONNECTION	12
1" CONNECTION	25
HOSE CONNECTIONS (WASH DOWN): 1/2"	6
3/4"	10
HOSE (50' LENGTH - WASH DOWN): 1/2"	6
5/8"	9
3/4"	12

FIGURE NO. 2

CITY OF ______________

WATER CUSTOMER DATA SHEET

CUSTOMER ______________ ADDRESS ______________

BUILDING ADDRESS ______________ ZIP CODE ______________

SUBDIVISION ______________ LOT NO. ______ BLK. NO. ______

TYPE OF OCCUPANCY ______________

FIXTURE		FIXTURE VALUE 35 PSI		NO. OF FIXTURES		FIXTURE VALUE
BATHTUB		8	×	______	=	______
COMBINATION SINK AND TRAY		3	×	______	=	______
KITCHEN SINK	- 1/2" CONNECTION	3	×	______	=	______
	- 3/4" CONNECTION	7	×	______	=	______
LAVATORY	- 3/8" CONNECTION	2	×	______	=	______
	- 1/2" CONNECTION	4	×	______	=	______
LAUNDRY TRAY	- 1/2" CONNECTION	3	×	______	=	______
	- 3/4" CONNECTION	7	×	______	=	______
SHOWER HEAD (SHOWER ONLY)		4	×	______	=	______
SERVICE SINK	- 1/2" CONNECTION	3	×	______	=	______
	- 3/4" CONNECTION	7	×	______	=	______
URINAL	- PEDESTAL FLUSH VALVE	35	×	______	=	______
	- WALL FLUSH VALVE	12	×	______	=	______
	- TROUGH (2' UNIT)	2	×	______	=	______
WASH SINK (EACH SET OF FAUCETS)		4	×	______	=	______
WATER CLOSET	- FLUSH VALVE	35	×	______	=	______
	- TANK TYPE	3	×	______	=	______
DISHWASHER	- 1/2" CONNECTION	5	×	______	=	______
	- 3/4" CONNECTION	10	×	______	=	______
WASHING MACH.	- 1/2" CONNECTION	5	×	______	=	______
	- 3/4" CONNECTION	12	×	______	=	______
	- 1" CONNECTION	25	×	______	=	______
HOSE CONNECTION (WASH DOWN)	- 1/2"	6	×	______	=	______
	- 3/4"	10	×	______	=	______
HOSE (50' WASH DOWN	- 1/2"	6	×	______	=	______
	- 5/8"	9	×	______	=	______
	- 3/4	12	×	______	=	______

COMBINED FIXTURE VALUE TOTAL ______

CUSTOMER PEAK DEMAND FROM FIG. 4.04 OR 4.05 × PRESS. FACTOR = ______ GPM

ADD IRRIGATION - ______ SQUARES × 1.16 OR 0.40[1] = ______ GPM

- ______ HOSE BIBS × 6.5 × ______ PRESS. FACTOR = ______ GPM

ADD FIXED LOAD = ______ GPM

TOTAL FIXED DEMAND = ______ GPM

[1] SPRAY SYSTEMS - USE 1.16; ROTARY SYSTEMS - USE 0.40

FIGURE NO. 3

WATER FLOW DEMAND PER FIXTURE VALUE-LOW RANGE

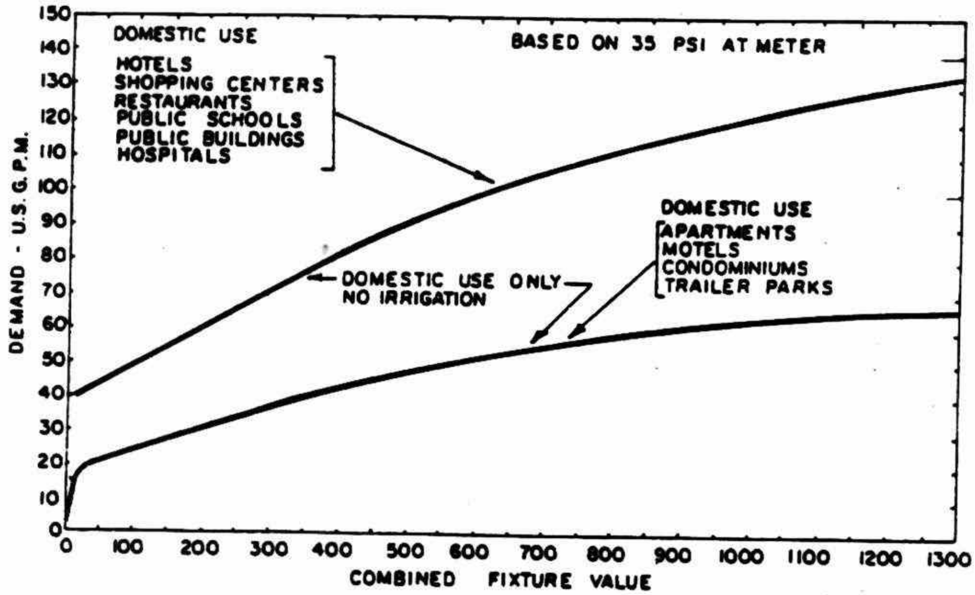


FIGURE NO. 4

WATER FLOW DEMAND PER FIXTURE VALUE-HIGH RANGE

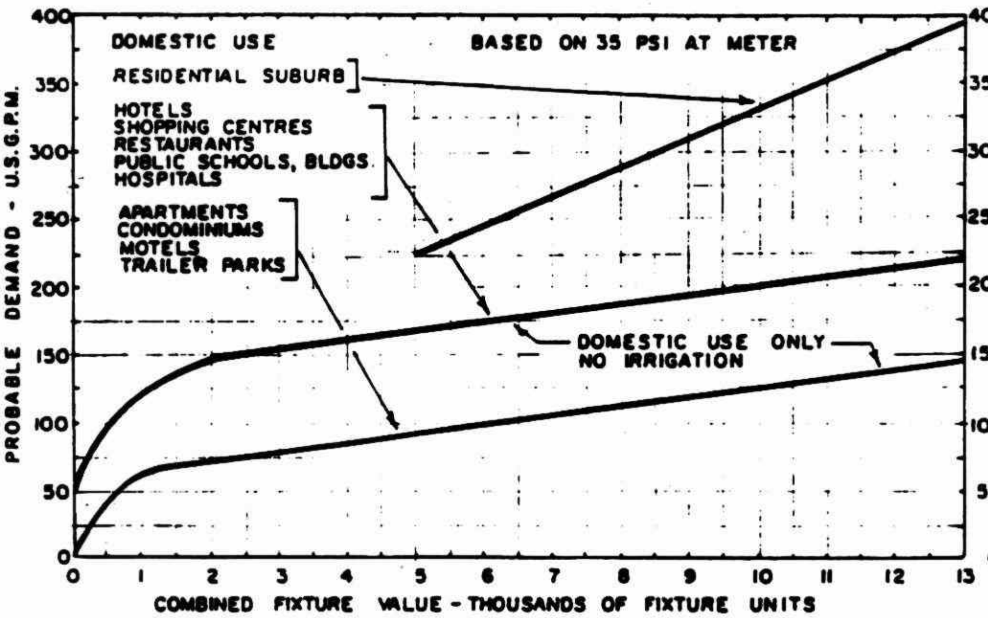


FIGURE NO. 5

FRICTION LOSS IN COPPER PIPES - C=130

	1/2"		3/4"		1"		1-1/2"		2"	
FLOW U.S.G.P.M.	VELOCITY F.P.S.	HD. LOSS PSI/100'	VELOCITY F.P.S.	HD. LOSS PSI/100'	VELOCITY F.P.S.	HD. LOSS PSI/100'	VELOCITY F.P.S.	HD. LOSS PSI/100'	VELOCITY F.P.S.	HD. LOSS PSI/100'
1	1.5	1.3	0.7	0.2						
2	2.9	4.5	1.5	0.8	0.8	0.2				
3	4.4	9.6	2.2	1.8	1.2	0.4				
4	5.9	16.3	2.9	3.0	1.7	0.7				
5	7.4	24.6	3.7	4.6	2.1	1.1				
6	8.8	34.5	4.4	6.4	2.5	1.6				
7	10.3	45.9	5.1	8.5	2.9	2.1				
8	11.8	58.9	5.9	10.9	3.3	2.7	1.5	0.4		
9	13.2	73.2	6.6	13.5	3.7	3.3	1.7	0.5		
10	14.7	88.9	7.3	16.4	4.1	4.0	1.9	0.6	1.1	0.1
12			8.8	22.9	5.0	5.6	2.2	0.8	1.3	0.2
14			10.3	30.6	5.8	7.5			1.5	0.3
16			11.8	39.1	6.6	9.6			1.7	0.4
18			13.2	48.6	7.4	11.9			1.9	0.4
20					8.2	14.5	3.7	2.1	2.1	0.5
25					10.3	21.9	4.6	3.2	2.7	0.8
30					12.4	30.7	5.6	4.4	3.2	1.1
35					14.2	40.9	6.5	5.6	3.7	1.5
40					16.5	53.3	7.4	7.5	4.3	1.9
45							8.4	9.4	4.8	2.4
50							9.3	11.4	5.3	2.9
60							11.2	15.9	6.4	4.1
70							13.0	21.3	7.5	5.5
80							14.9	27.2	8.5	7.0
90							16.7	33.8	9.6	8.2
100							18.6	41.0	10.7	10.6

FIGURE NO. 6

APPROXIMATE FRICTION HEAD OF VALVES AND FITTINGS IN EQUIVALENT FEET OF STRAIGHT PIPE

PIPE SIZE IN.	CORP STOP FT	CURB STOP FT	GATE VALVE FT	GLOBE VALVE FT	ANGLE VALVE FT	SWING CHECK FT	SHORT ELL FT	LONG ELL FT	45 DEG BEND FT	TEE-SIDE OUTLET FT
1/2	6.1	3.1	0.4	16	8	3	1.5	1.1	0.8	3
3/4	5.9	4.0	0.5	22	12	5	2.2	1.4	1.0	5
1	6.7	3.8	0.6	27	15	7	2.7	1.7	1.3	6
1-1/4	7.5	3.6	0.8	37	18	8	3.7	2.4	1.6	8
1-1/2	7.7	4.4	1.0	44	22	10	4.3	2.8	2.0	9
2	8.4	4.8	1.2	57	28	13	5.5	3.5	2.5	11
2-1/2			1.4	66	33	17	6.5	4.2	3.0	14
3			1.7	85	42	20	8.1	5.1	3.8	17
3-1/2			2.0	99	50	23	9.5	6.0	4.4	19
4			2.3	110	58	27	11.0	7.0	5.0	22
5			2.9	140	70	33	14.0	8.9	6.1	27
6			3.5	160	83	40	16.0	11.0	7.7	33
8			4.5	220	110	53	21.0	14.0	10.0	43
10			5.7	290	140	67	26.0	17.0	13.0	56
12			6.7	340	170	80	32.0	20.0	15.0	66

FIGURE NO. 7

METER LOSSES - PSI

DISK TYPE METERS

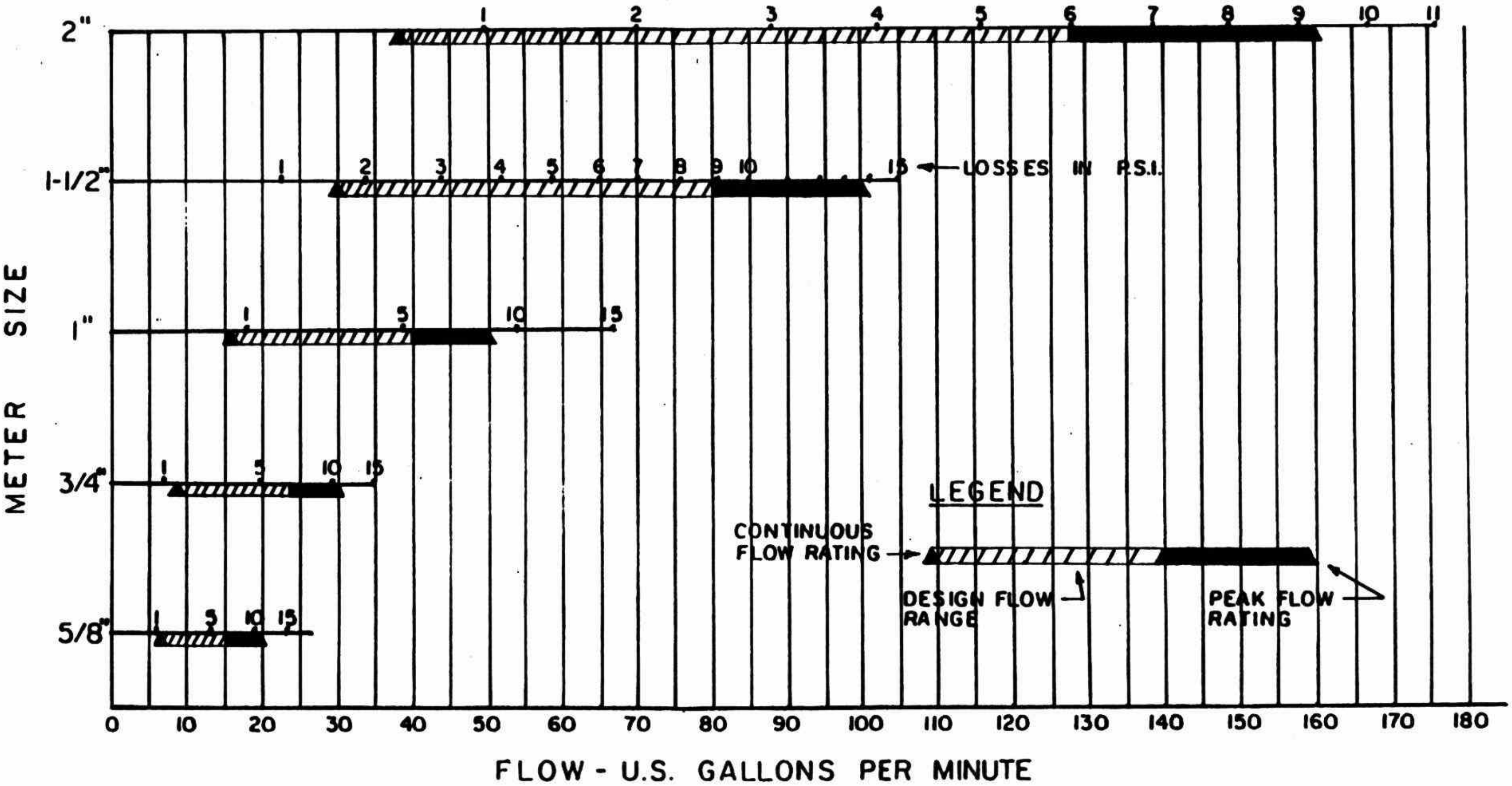
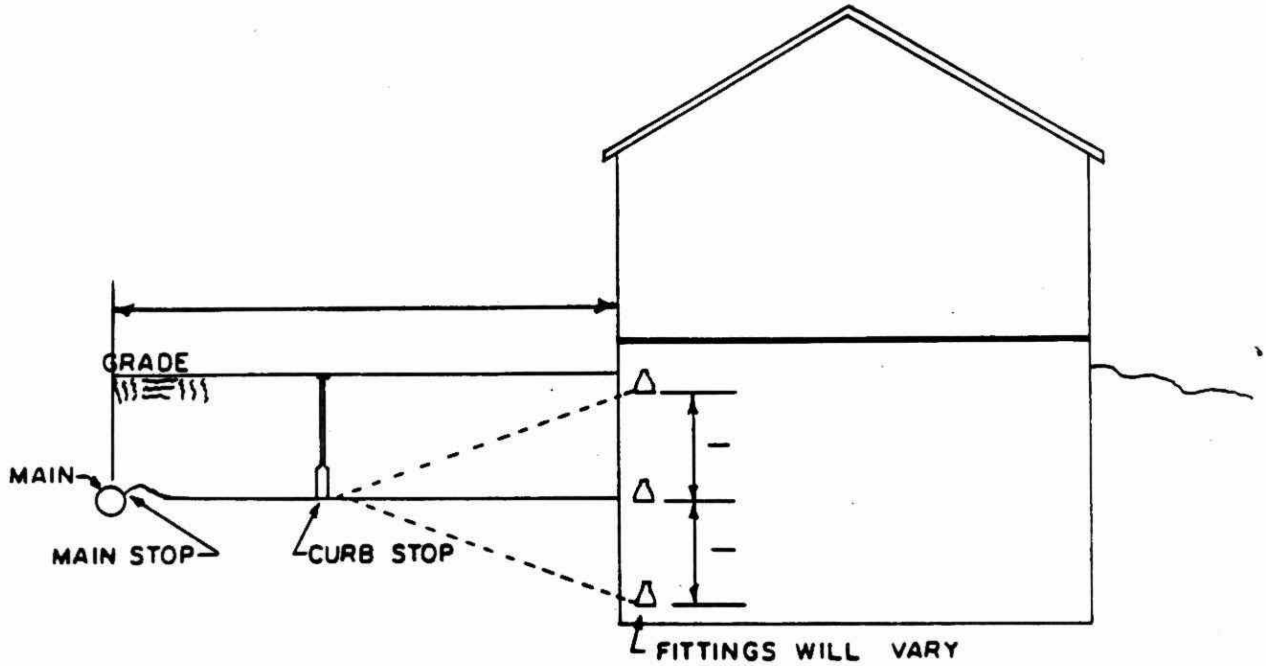


FIGURE NO. 8

SERVICE SIZING CALCULATION



CALCULATION

DATA

SERVICE SIZE ____ MATERIAL ________ FLOW RATE ________

CALCULATION FOR ________ FLOW RATE

MAIN PRESSURE -- [ ]

LOSS - PIPE AND FITTINGS

LENGTH OF PIPE ________

EQUIVALENT LENGTH FOR FITTINGS

CORPORATION STOP ________

CURB STOP ________

GLOBE VALVE ________

____

____

EQUIVALENT LENGTH-PIPE AND FITTINGS ________

LOSS PER 100' OF PIPE (FROM TABLE) ______ PSI

LOSS FOR EQUIVALENT LENGTH ------------------ [ ]

METER LOSS FROM TABLE -------------------- [ ]

TOTAL LOSSES ---------- [ ] [ ]

PRESSURE AT METER OUTLET AFTER LOSSES ------------------ [ ]

PRESSURE CORRECTION FOR ELEVATION DIFFERENCE

FT. DIFF. X .43 P.S.I (____________) ---------- [ ]

PRESSURE AT METER OUTLET ---------------------- [ ]

SUBJECT:

WATER DISTRIBUTION
SYSTEM OPERATIONS

TOPIC: 10

Safety

OBJECTIVES:

The trainee will be able to:

1. List the four major causes of accidents leading to death/disability.

2. Recall the safety procedures for:-
   a. Control of traffic at a work site
   b. Trench work
   c. Entry into confined spaces.

3. Recognize the electrical hazards which are present.

4. Recall the application of a Ground Fault Circuit Interruption.

5. Demonstrate the use of:-
   a. Air Packs
   b. Combustible Gas Analyzer
   c. The GAS TEC

6. Recall the permissible levels of dangerous gases likely to be encountered.

SAFETY

GENERAL

Regardless of laws or apparent degree of responsibility, safety on a construction site is everybody's business. In general terms, it can be said that employers (e.g. municipalities) are becoming more conscious of the economic benefits that are derived from good safety practices, along with the obvious benefits to the workmen themselves. Employers and employees are governed in their actions by The Occupational Health and Safety Act, 1978 and Ontario Regulation 659/79 and by the references to safety in the contract documents. These provide protection for personnel by requiring certain standards of conduct of the constructor and the equipment on the project.

The dangers associated with system operations emphasize the need for safety practices. Physical injuries are a continuous threat and occur with regularity. Explosions and asphyxiations from gases or oxygen deficiency occur. Although infrequent at any particular location, such accidents are a daily happening. These occupational hazards may be largely avoided by the execution of safe practices and the use of safety equipment. The dangers are many and carelessness all too frequently prevails until an accident results. Then it is too late.

It is the responsibility of supervisors and workers to acquaint themselves with the hazards associated with system maintenance and operation and to take steps to avoid them. Accident prevention is the result of thoroughness and the application of a few basic principles and knowledge of the hazards involved. It has been said that the "A, B, C", of accident prevention is "Always Be Careful". One must learn how to be careful and what to avoid. With this knowledge one can then always think and practice safety.

It should be noted that the four major causes of death and disability are:

1. cave-ins
2. contacts with electrical power sources
3. Unprotected power tools
4. falls

RESPONSIBILITIES

The administration and enforcement of the Act described in this Topic is by the Ministry of Labour, under the Director of the Construction Health and Safety Branch and his Inspectors. These Inspectors make periodic visits to all construction projects under their supervision, and it is their responsibility to deal directly with the employer. They will leave written instructions with the employer for any infractions which have to be corrected, and the instructions are to be acted on without delay.

The Act itself is concerned with the assigning of responsibilities to all engaged in construction and those appointed by the Province to administer the Act. It outlines the actions that should be taken on finding contraventions of the Act, or after an accident has happended.

The important thing to be remembered by all those working on the project is that the Ministry of Labour Inspectors have wide powers under the Act. There are certain procedures to be followed after an accident occurs. The individual in charge of the project must ensure that these are followed.

Part V deals with the refusal to work where health or safety is in danger, and Section 23 (3) and (4) should be studied.

In the event that a Municipality proposes to do the work using its own forces, the Municipality writes to the Ministry of Labour giving notice that construction is to commence, and designates the municipality as the Owner.

The Municipality would then have to designate themselves as the constructor, as they are performing the work.

The employee whom they designate to look after the work would be the job superintendent.

The responsibilities of these people are laid out in the Act and in the definitions.

The significant part is that the Municipality would be accepting the responsibility as a constructor.

Part II, Administration, gives details to the contractor on the selection of a health and safety representative, and his duties (Section 7).

The duties of the constructor, employer, supervisor, worker, owner and supplier are set out in Part III. The inspector is classed as a worker under the Act and the employer would be the municipality or agency for whom the inspector works. The owner may or may not be the employer, as far as the inspector is concerned. This is noted here, as the owner and/or employer has responsibilities with respect to the worker, and the inspector should be aware of this (Sections 14 and 18). The worker's obligations are contained in Section 17.

REGULATIONS

There are three sets of Regulations under the Act.

O. Reg. 658/79 - Industrial Establishments

O. Reg. 659/79 - Construction Projects

O. Reg. 660/79 - Mines and Mining Plants

The sewer and watermain worker would be interested in O. Reg. 659/79 for Construction Projects. Section 1 defines terms which apply throughout the Regulation. These should be fully understood, i.e. trench and shaft. Questions to the Ministry of Labour frequently are answered by reference to the definitions.

The remaining sections of the Regulations are divided as follows:

Part I - Administration - Sections 2 to 12

Part II - General Construction - Sections 13 to 165

Part III - Trenching - Sections 166 to 177

Part IV - Tunnels and Shafts - Sections 178 to 238

Part V - Work in Compressed Air - Sections 239 to 293

Note that Parts I and II apply to all projects.

Part II - General Construction - Section 13 to 165

General - Sections 13 to 20

These Sections are concerned with general requirements on construction sites.

Public Way Protection and Traffic Control - Sections 21 to 27

Sections 21 and 22 refer for the most part to construction sites adjacent to public thoroughfares. However, the constructor is required to abide by all local by-laws as well.

The individual in charge should be provided with or know any local regulation regarding the control procedures which would be used. This would include such details as:

a) Properly attired, trained and equipped flagmen.

b) Adequate delineators to channel the flow of traffic.

c) Adequate flasher barricades and traffic signs. Continuous servicing of barricades, particularly during the night hours.

d) Snow fencing or other required fencing along the trench excavation to separate the working area from the traffic flow and to protect pedestrians.

Personal Equipment, Protective Clothing, Equipment and Devices - Sections 28 - 37

Safety hats and safety footwear must be worn at all times. Safety glasses are required when doing work which could result in eye damage.

It should be noted that workers are to be instructed in the care and use of such equipment as they may require in any given situation.

Access to and Egress from Work Areas - Sections 38 - 40

It quite often happens that adequate provision for entering and leaving a trench is an item that is abused in the general rush to get on with the job.

Housekeeping - Sections 41 - 46

Good housekeeping near the trench is important to prevent any objects from falling on persons in the trench. It is good practice to maintain all parts of the work in a tidy condition. It can contribute much to the reduction of accidents on the project and also provide a more efficient and economical operation.

Not all the Sections noted above may apply to trench work but can give food for thought.

Storage of Materials - Sections 48 - 52

These Sections deal with the storage of various materials. In many ways these Sections are related to Housekeeping.

Excavations - Sections 53 to 57

Sections 56 and 57 should be noted. Section 56 defines when the walls of an excavation should be supported. Reference should be made to Sections 161 and 167 on support systems for trench walls.

Section 57 gives requirements for entering caissons or wells.

Ladders - Section 68 to 75

The worker should note the correct construction, use and maintenance of ladders. Note also Section 177.

Hygiene - Section 88 to 91

These Sections give details of facilities that are to be made available to workmen. It will probably prove to be interesting reading to many, particularly those who are involved in relatively small projects of short duration.

Fire Protection - Sections 92 to 96

These Sections are concerned mainly with fire protection in buildings and so do not have many applications to sewer and watermain construction. Section 94 does deal briefly with tunnel work, and fire protection for tunnels is covered in more detail in Sections 180 to 187.

Electrical Hazards - Sections 100 to 105

Particular attention should be given to Section 105 regarding safe distances from power lines. A careless attitude to this regulation, particularly by operators of excavating equipment is one of the major causes of accidents in trench work, and a supervisor should always be aware of any deviation from the requirements of the regulations.

Explosives - Section 109 to 118

These Sections of the Regulation detail requirements when explosives are used on the project. These

Sections by no means cover all the regulations with respect to the use of explosives. There may be in addition local by-laws regarding use of explosives. If the use of explosives is anticipated on a project, the various regulations will be specified, probably as follows:

> "The supplying, hauling, handling and storing of all explosives and accessories shall be done in accordance with the rules and regulations of the Explosive Division, Department of Energy, Mines and Resources, Ottawa; The Occupational Health and Safety Act and Ontario Regulation 659/79".

Confined Spaces - Section 119

Workers should carefully study this Section, as it will be found that the very nature of the work will require entry into confined spaces on both new work and existing systems. See appendices A & B. *Detailed records must be kept.*

Equipment, General - Sections 120 to 135

The supervisor should note Section 130 regarding use of a signalman when the view of an operator is obstructed.

Part III - Trenching - Sections 166 to 177

These Sections are very important, and will probably be referred to more than any other during the course of a project.

Application - Section 166

This Section gives the conditions when the requirements apply to a trench.

Interpretation - Section 167

This Section gives the various definitions used when referring to trench work.

Support System - Sections 168 - 177

Sections 168 to 170 note situations where trench support is required.

Section 171 gives the time when a support system shall be installed or removed.

Section 172 includes the table of sizes for shoring members. It also gives a description of the various soil types used to determine the type of support system to be used. Both tables are straight forward and should not present any difficulties in interpretation.

Section 173 gives how a system of timbering and showing is assembled.

Section 175 gives the requirements for a prefabricated trench support system. This is usually a fabricated steel open-ended box which is dragged along the trench as the work proceeds. Steel interlocking sections now available would also be included in this category.

It should be noted that stamped, approved shop drawings are required before the use of these systems or similar support is allowed, and a copy of these drawings is to be kept on the site.

Section 176 allows the use of metal trench-jacks in place of wooden struts, providing the jack is equal to or exceeds the allowable working load of the strut.

Part IV - Tunnels and Shafts - Sections 178 to 238

These sections of the Regulation deal with tunnels caissons and similar work, and would apply on projects where tunnel work was called for, regardless of the length of the tunnel.

Fire Protection - Sections 179 to 200

These Sections include fire protection, first aid and communications.

Fire can be particularly hazardous in the confined space of a tunnel and good housekeeping is an effective fire prevention measure.

Section 236 calls for adequate ventilation or regular testing of the air for gases or oxygen deficiency. The supervisor should satisfy himself that such testing is, in fact, being done, recorded and signed in a log book.

Part V - Compressed Air - Sections 239 to 292

This part of the Regulation deals with work in compressed air.

SUMMARY

A sharp eye and a questioning mind often can prevent problems and thus reduce the work load.

The supervisor can work up a routine for checking safety on the project which can be carried out when he walks on the site in the morning.

1. Are barricades, delineators, signs, flashers, etc., in place and in working condition?
2. Are workmen wearing personal safety gear?
3. Are the sides of the trench clear for walking and working? Is the backhoe casting well clear of the trench? Are all pipes clear of the edge of the excavation?
4. Are ladders in place for easy access and egress?
5. Is the operator keeping the backhoe boom well clear of hydro wires?
6. Are the sides of the trench stable?
7. Are there any cracks in the pavement or ground surface near the trench, indicating possible ground movement, and extra weight on trench shoring?

These items can be checked very quickly and deviations from normal practice may indicate that the workers are becoming careless in safety procedures.

THE SYSTEM SAFETY PROGRAM

General

Before starting a safety program, the full co-operation and active support of management is needed. One person in the utility organization must be responsible for the program. In a small system, that person may be the superintendent, while in a large organization, another person who can devote part or full time to the job can be appointed.

The next step in setting up the program is to provide for:

1. Keeping injury records

2. Identification and location of the hazards

3. Making equipment, work sites and working methods safe

4. Getting employees interested in safety

5. Controlling work habits

Injury Records

The keeping of injury records is basic to a safety program. With complete records, the program is given direction and is sure of success. The records should be kept brief but must contain all pertinent data. The forms should cover such items as:

1. Accident report

2. Description of accident

3. Physician's statement

4. Corrective action taken

5. Accident analysis chart

Except for minor injuries, wounds should be treated by a doctor and reported for possible Workman's Compensation. Service truck must have first aid kits. It is recommended that all personnel should receive "St. John Ambulance" first aid instruction.

It is a "Compensation Board" regulation that when five (5) or more people work as a group on any shift, one of them is required to hold a "St. John Ambulance Certificate" in first aid. Remember, no cut or scratch is too minor to receive attention.

Appendix C describes First Aid and Resuscitation Procedures.

Locating the Hazards

The person responsible for the safety program should be constantly on the alert for hazards which may cause an injury to an employee. One of the best methods of attacking this problem is to search the records for the conditions and situations that have produced injuries. Records like this show the need for a corrective program.

Many other sources of information on hazardous conditions are available. These include safety manuals, insurance company brochures, etc. They should be used freely and frequently.

Equipment, Working Site, Working Methods

Nothing prevents an accident as effectively as the elimination of the cause. To preach safety while permitting unsafe conditions will discourage the cooperation required from employees. Only when safety is integrated with the job are workers convinced that the man responsible for safety wants to prevent accidents.

Some Protective Safety Equipment

The need for protective safety equipment in an accident prevention program has proven its value many times; the program cannot be successful if any phase of accident prevention is overlooked.

1. Use safety equipment as it was meant to be used. This should be compulsory during the performance of hazardous jobs.

2. Protect eyes and face when there is any possibility of injuries from hand tools, power tools, welding equipment, etc.

3. Protect feet with safety shoes to safeguard against injuries while breaking pavements, tamping trenches, handling materials, etc.

4. Protect head (with hard hats) to prevent serious injuries in construction, excavation or electrical work.

5. Protect hands (with gloves) to prevent injuries from occurring when handling materials, sharp objects, chemicals or electrical equipment.

6. Use air packs when hazards such as painting or dusty areas exist. See Appendix D.

7. Prevent accidents due to falls by using safety belts, scaffolds, etc.

GENERAL SAFETY PROCEDURES

When working, observe the following common sense rules:

1. Keep walkways clear of loose objects such as pails, shovels, loose rope, etc.

2. Wipe up grease and oil immediately; salt or sand icy walks.

3. Pick up all tools, clean them and return them to their storage area.

4. When it is necessary to use tools in an empty tank or manhole, etc., lower them in a pail

on a rope and remove them in the same way. Brooms and shovels can also be transported by rope. Do not attempt to climb up and down ladders with your hands full of tools.

5. Do not overload yourself when using stairways. Keep your load small enough to be able to see over it. Always keep one hand free to use the hand-rail.

6. Do not try to climb up or down a ladder or over a railing when handling a hose under pressure.

7. Always wear hip wader rubber boots with good treaded soles when washing down any equipment or structure. Do not wear rubber boots with worn soles and heels.

8. Always wear the rubber clothing provided when working in a narrow or confined passage where dirt accumulates.

9. Always wear rubber or plastic coated, waterproof gloves when cleaning pumps, handling hoses, removing grit or sludge, etc.

10. When it is necessary to use an extension ladder always lash the ladder to a hand-rail or other secure object.

11. Always wear hard hats.

12. Do not hang clothes on electrical disconnect handles, light switches or control panel knobs.

13. Replace all manhole covers, protect them with guard-rails if it is necessary to leave them open.

14. Use the proper tool when removing or replacing manhole covers. Do not attempt to move or close a manhold cover with your hands.

15. When working in manholes located in a street or road, post signs with blinking amber lights and red flags at each approach to the area.

16. Do not pull up grit-filled pails by rope. Use an "A" frame and pulley or some other type of support with a pulley. Be sure the support and pulley are fastened firmly to prevent them from toppling over during use.

17. Always wear a safety belt with a short rope and a safety snap when leaning out through railings.

18. Be very careful during repair work on fuel systems of gasoline engines. Close the shutoff valve from the tank and be sure there is adequate ventilation while draining the fuel system.

19. Check the ventilation of any enclosed or under-ground areas.

20. Do not refill a gas engine when in operation or while still hot. Remove spark plug from engine before cleaning out a pump unit.

Building Maintenance

Periodic inspections are necessary to eliminate hazards (fire safeguards, etc.). Suggested repairs for safety should receive immediate attention. Floors, hallways, and stairways should always be well lighted, clean,

orderly and free from oil, dirt and debris. Immediate repairs of hazardous electrical outlets and fixtures should be routine. Adequate sanitary facilities for employees must be provided. Hand-rails on steps and stairways should always be provided and used. Good housekeeping must be maintained.

Hand Tools

Hand tools are the cause of many accidents and injuries when improperly used and in unsafe condition. Therefore, use the right tool for the right job in the right way. Use protective safety equipment where there is a job hazard. Keep the work area clear of hazards, with plenty of working space for solid footing. Tools should be in good condition and used for the purpose for which they were intended.

Portable and Power Tools

All equipment should be grounded. Check wiring and equipment regularly for defects. Be very careful when using equipment in wet areas. Use protective safety equipment when operating grinders, buffers, or other tools when there is danger of flying material.

Tools and Machines

Use protective equipment when operating power equipment if there is any chance of flying objects or other injuries. Inspect all tools and equipment for safe operation. Necessary repairs or replacements should be made immediately. Repair power tools and machinery only when the equipment is turned off.

Welding

Use the proper protective equipment at all times. Check for fire hazards before cutting or welding in areas of inflammable or explosive mixtures. Only authorized per-

sonnel should operate welding equipment. The Ministry of Labour requires a 2 3/4 lb fire extinguisher be fastened to the welding truck.

Inspections of Tools and Equipment

Periodic inspections should be made of tools and equipment so that those that are broken or worn out may be replaced. Report worn or broken equipment and be sure they are replaced or repaired as soon as possible.

Ladders

Ladders should be inspected periodically and maintained in good order. Use safety belts when awkward positions are necessary for the work. Do not use metal ladders for electrical work.

Lifting

Always lift with the leg muscles instead of the back and be sure your footing is secure. Bend your knees and keep your back straight. Don't turn or twist your body when lifting. Get help if load is too heavy or awkward to handle. Use mechanical device for lifting wherever possible.

Sanitation

Washrooms, toilets, locker rooms, drinking fountains and shwers that are clean, ventilated and adequately built are good for employee morale. Clean drinking water and paper cups should be available, especially if the employees are exposed to skin irritant materials. See Appendix D.

Storerooms

Good housekeeping must be maintained at all times. Space should be well arranged to permit proper storage,

handling and movement of materials. Inspections should be made regularly for fire hazards. Fire extingusihers should be in good order and easily accessible.

Working Area

A safe working area must be provided for efficient work. In the field, traffic should be controlled by the use of traffic cones, barricades, flags, etc., to protect the workmen as well as the public. In the material yard and storerooms, good housekeeping and properly planned storage and work areas must be provided for safe working practice. Shops, plants and offices should be planned for the most efficient production.

Trucks and Equipment

Routine inspections of trucks and equipment should be made. Any need for repairs should be reported and acted on as soon as possible. Only qualified and licensed operators should be permitted to use and operate vehicles and equipment. Never permit riders on trucks or other mobile equipment. Check electrical and any other hazards constantly when moving heavy equipment. All trucks should be equipped with first aid kits, fire extinguishers, and flares.

Barricades and Traffic Control

An adequate and safe work area must be protected. Sufficient traffic cones and barricades should always be carried by crews assigned to construction or maintenance work in streets. Paint barricades bright, visible colours and keep them in good condition. Be sure warning signs, flags, flares are adequate and in positions where they can be easily seen.

Equipment Servicing

When servicing plant and equipment, Do Not:

1. Grease or oil or attempt to service any machinery while it is in operation. Pumps on automatic control must be locked out and key carried by the operator during servicing.

2. Make any adjustments to operating machinery while alone. If it is necessary to run the unit to adjust it, a second man must be present and be beside the stop and go switch.

3. Work around electrical panels, disconnects or switches alone.

4. Enter any crawl space under flooring for any purpose until the area has been ventilated. A second man should be present.

5. Service pumps and shafts without shutting off all pumps and locking them out.

6. Under any circumstances, attempt to grease or service pump shafting while standing on beams, piping, loose planks, guard rails, or by leaning out, over or through guard rails. If a ladder must be used, then a second man must be present to hold the ladder steady and to provide any other assistance.

PRECAUTIONS FOR ELECTRICAL MAINTENANCE (See Appendix E)

1. Plan safety into each job. Orderliness and good housekeeping are essential for your safety and the safety of others.

2. Each employee shall be qualified both in

experience and general knowledge to perform the particular electrical work which he is assigned.

3. Study the job carefully to determine all of the hazards present and to see that all necessary safeguards and safety devices are provided for safe working conditions.

4. Examine all safety devices before they are used to ensure that they are in good condition.

5. In all cases where work is being performed on or close to live conductors or equipment, at least two men shall work together. When it is necessary for one to leave, the other workman shall not continue the work until the first man returns.

6. Consider the results of each action. There is no reason for you to take chances that will endanger yourself and others.

7. Satisfy yourself you are working under safe conditions. The care exercised by other can not be relied upon.

8. Wear close fitting clothing, keep sleeves rolled down, avoid wearing unnecessary articles while working on or close to live circuits or apparatus.

9. Use only approved types of rubber or leather gloves.

10. Protect yourself by placing an insulated medium between you and ground or grounded apparatus to keep any part of your body from

providing a path for electrical current when working on conductors or appartus that may be energized.

11. Use rubber mats when working on any electrical control panel or switch and disconnect boxes.

12. Open and close switches completely with a firm positive motion, Switches in a partly open position may arc or cause a flash-over with damaging results to the switch and possible injuries to the operator.

13. Open switches fully before removing fuses. To remove a fuse from a circuit carrying a current without opening the switch is particularly hazardous. Use an approved low-voltage fuse puller to remove fuses on a circuit of less than 500 volts (where no switch is provided) whether a disconnect is provided or not. Remove fuses by breaking contact with the hot side of the circuit first. Use the reverse procedure when replacing fuses. Insert the fuse in the cold terminal first.

14. Do not stand directly in front of panel to remove fuses or shut off disconnects.

15. Shut off the power when examining or making repairs or alterations on light and power circuits. When this is impractical Head Office must be contacted for further instructions before proceeding with the work.

16. Consider all electrical circuits to be dangerous. Treat dead circuits as though

they were alive. This may prevent an accident as the circuit may be closed through an error of some other person.

17. Exercise extreme care when required to locate troubles on a series lamp circuit, before repairs are made make sure the power is cut off.

18. Lock or block open the control devices, open disconnect switches or remove fuses before examining, repairing or working on power circuits. After these precautions have been taken, attach tie-up tags worded "WORKMEN ARE WORKING ON LINE." The tag shall bear the name of the workman. Tie-up tags shall remain on the opened devices until removed by the workman whose name appears on the tag. If the workman leaves without removing his tag, it may be removed only on authorization of Head Office.

19. Before working on line circuits at a point remote from the control switch, which has been tagged, it is recommended that the conductors be grounded at a point on the line between the switch and the work station.

20. Make a complete check of the circuit before applying power for the first time. This is to be done by a qualified man in charge of the repairs, all other workmen to stand off at a safe distance.

FIRE PROTECTION

Good housekeeping is the basis for fire prevention. Inspections should be made periodically and correction of fire hazards should be made as soon as possible.

Consult local fire departments for recommendations.

Each individual should have first-hand knowledge of a fire extinguisher, its ABC rating point of contact and time of operation.

A CO_2 fire extinguisher can only be used in an open area where the chance of using up the local oxygen is minimal. Never grab the horn of the extinguisher to direct the CO_2. The gas being expelled will freeze your hand to the horn causing serious injury. There is a handle provided. Do not direct the CO_2 at anyone. To fight the fire you must approach the fire from upwind, pull the pin and aim directly on the burning area.

The approximate operating time for CO_2 fire extinguishers is as follows:

2½ lb.	10 sec.	$\pm$ 2 sec.	2. BC.
5 lb.	14 sec.	$\pm$ 2 sec.	4. BC.
10 lb.	14 sec.	$\pm$ 3 sec.	6. BC.
15 lb.	25 sec.	$\pm$ 4 sec.	8. BC.
20 lb.	30 sec.	$\pm$ 4 sec.	8. BC.

<u>Note</u>:

1. The 2. BC etc., refers to the type of fires and area the extinguishers covers. (BC) indicates electrical, gas, oil type fires, "A" type are wood, paper, etc., CO_2 will not be effective on "A" type fires.

2. (2) indicates the extinguisher will put out a fire of not more than 2 square feet in area.

3. Weight indicated refers to contents only.

A Dry Chemical extinguisher can be used in any area. Approach from upwind and pull the pin. You do not have to stand as close to the fire as with CO_2. Dry Chemical will put a blanket of chemical over the fire, smothering it.

NOTE:

1. All extinguishers must be refilled after using no matter what amount has been used.

2. All extinguishers must be hydrostatically tested every five years.

HANDLING AND STORAGE DANGEROUS MATERIALS

The Occupational Health & Safety Act, states that the employer is reasonable for providing the necessary protective equipment and clothing for handling dangerous materials. It is the responsibility of the employee, both to his employer and to himself, to use and maintain them.

Eyewash fountains and deluge showers must be located within fifteen (15) feet of the entrance to any chemical handling area. Plenty of water should be available for washing up after handling chemicals. Protective clothing should be washed after use.

All areas where solvents or other compounds are used and stored must be well ventilated. The working area must be designed and constructed for the safety and convenience of the worker and for his efficient production. The ventilation should be by mechanical means with the air intake drawing air from the outside. In rooms where lime and other dry types of chemicals are used, install dust accumulators in the air discharge pipe.

Operate exhaust fans when handling any chemical whether liquid or dry.

Wear rubber boots, apron, gloves and eye shield or goggles when handling liquids. Wear nose and mouth filter masks and goggles when handling dry chemicals.

Characteristics of Dangerous Gases and Gas Fuels

Refer to Appendices F and G.

WET WELLS

A wet well is classified as a confined space. Before entering, the worker must:

1. Test for oxygen content using an oxygen meter. DO NOT ENTER unless the oxygen content in the atmosphere registers between 18% and 23%.

2. Test the noxious gases and vapours using a combustible gas analyzer.

3. Test for Hydrogen Sulphide using the colorimetric test. Tests for other gases may also be necessary.

The worker must also take the following precaution on entry:

1. If any atmospheric contamination is suspected, a fixed or portable vent fan of 700 cfm capacity must be used before and during entry. If no vent fan is available, a portable air pack must be worn.

2. Explosion and waterproof lighting must be used.

3. An opertor with a man hoist must be located at all times at the entrance to the wet well

to monitor the meters and observe the operator inside.

4. If a man hoist is not available two operators must be at the entrance.

5. A parachute type harness and lifeline and hard hat must be worn.

6. A step-through parting is required at the ladder entrance. See Appendix A.

DRY WELL

1. Vent fan shall be started before entering the pumping station and left operating continuously while the operator is in the station.

2. "DANGER PUMPS ON AUTOMATIC CONTROLLER" signs should be posted at the control panel floor level, and the pump floor level.

3. "NO SMOKING" signs should be posted at the pump floor level.

4. Lock out switches at control panel when working on any pump at any floor level.

APPENDIX A

SAFE ENTRY INTO CONFINED SPACES

INTRODUCTION

Providing an effective safety programme for entry into confined spaces is the duty of the employer. This duty requires attention to details that, if they are overlooked or disregarded, can result in injury or death to the employee involved. This duty has both moral and legal obligations for the employer.

The moral obligation is easily defined as: "virtuous conduct according to civilized standards of right and wrong." In other words, We are our brother's keeper: Everyone understands this tenet and most people try to live up to it.

The legal obligation is much more complicated and is spelled out, in the Ontario Government safety legislation. The employer's responsibility is to follow the existing legislation and to provide a safety programme. The employees legal responsibility is also spelled out in the Ontario safety legislation.

There are several definitions of confined space. One states: "Any space, having a limited means of egress which is subject to the accumulation of toxic or flammable contaminants or has a deficient or an excessive oxygen atmosphere". Limited means of egress would be some place that is hard to get out from in a hurry. Toxic or flammable contaminants are materials such as dust, marsh gas, solvents, natural gas, fuels, carbon-monoxide sewer gas,

hydrogen and hydrogen sulphide (an odour like rotten eggs). There are also oxygen deficient atmospheres caused by carbon dioxide, nitrogen, helium, bacterial action, methane, etc. which dilute the air.

Many waterworks employees relate a confined space to valve chambers and vaults. A narrow trench, large pipe and meter-pit will also qualify as a confined space. If one must enter a valve chamber to do valving for a shut down, one must use knowledge, skill and intelligence to do it safely and not rely on chance and luck to prevent injury.

The extent of the problems facing workers entering confined spaces are as follows: explosive atmospheres; toxic atmospheres; deficient or excessive oxygen; corrosive atmospheres; temperature extremes; burial by bulk materials; restricted mobility; combustible material; electricity and poor lighting.

COMBUSTIBLE VAPOURS AND GASES

This is indeed a large group of substances which is increasing constantly due to modern technology. The common hazards are hydro-carbon fuels, solvents, alcohols, paint thinners, natural gas and marsh gas.

They may be simple elements (hydrogen) or complex compounds, having the common characteristic, that when mixed with a certain proportion of air, and an ignition spark of the right temperature, can cause them to burn or explode.

Natural gas if it is leaking from a piping system can be detected by its odour. Some natural gas from a well or a transmission line may be practically odourless. It is non-toxic but it can replace the oxygen content of the atmosphere and it may cause asphyxiation. When leaking into the soil it normally follows the path of least resistance and often finds its way into duct lines, conduits, sewers,

drains, manholes, vaults, pits as well as building foundations.

Gasoline and diesel fuels from tank leaks and spillage normally end up floating on the water table and are found in all kinds of underground structures. You can smell them, and in strong concentrations they can be toxic and cause suffocation by replacing the oxygen content of the air.

Marsh gas is a colourless, odourless gas produced by natural decomposition of garbage and other organic material. It is common in marshes, swamps and bogs. It is mostly methane and readily spreads through the soil into underground structures. It is non-toxic but it also can dilute the oxygen content of the air causing suffocation.

Sewer gas is produced by the decomposition of sewage material. It is mainly methane with traces of hydrogen sulphide which has a smell like rotten eggs. Hydrogen sulphide is nearly as lethal as cyanide (10 p.p.m. THRESHOLD LIMIT VALUE). Sewer gas rarely occurs in flowing sewer systems. However, other combustibles are commonly found in sewer systems, where they may be associated with a sewer smell.

Propane and butane are colourless and heavier than air. Commercial butane and propane has an odourant material normally added to it.

Commercial solvents spilled or leaking from above, or below, ground tanks penetrate the soil and generally float on the water table. Solvents may be toxic as well as explosive. They could be odourless.

Natural occurring hydrogen is a by-product of acid action, bacterial action, and electrolysis. Being odourless and colourless and lighter than air it will collect in high corners of vaults and man-holes, a very good reason to have

ventholes in all manhole lids. Hydrogen is explosive 4% to 74% when mixed with air. It may act as an asphyxiant by reducing the oxygen content in the air.

Methane can be evolved from overheating polyethelene sheathed cables.

Combustible gas indicators were developed 50 years ago by employees of the Standard Oil Company. Today they are standard equipment used in the safety programmes in mining, petroleum, chemical, utility and fertilizer industries.

These combustible gas indicators are usually calibrated to measure a particular gas in percent of the lower explosive limit (L.E.L.) or percent of gas in the air. Combustible gas indicators of the basic hot wire type that are sensitive to the heat of combustion are available from a number of manufacturers. They can be portable or stationary to monitor a working atmosphere.

TOXIC VAPOURS

Simple asphyxiants may be any vapour which, when mixed with the atmosphere, reduce the oxygen content below the critical level. Carbon-dioxide, nitrogen or helium are actually non-toxic but they can dilute the air to such an extent that an oxygen deficiency results. Carbon monoxide most commonly occurs because of incomplete combustion. It is a flammable, colourless, odourless, tasteless gas which is highly toxic in very small concentrations. The Ontario Ministry of Labour has accepted a 35 p.p.m. of carbon-monoxide as the threshold limit for an eight hour time weighted average with an allowed peak of 200 p.p.m. not to exceed 15 minutes.

One must remember that the human blood will absorb carbon-monoxide (CO) up to 300 times faster than oxygen.

People who smoke or work in smoky areas or are in areas with high automobile density will consistently have greater carboxyhaemoglobin saturation than people not so exposed. Therefore, the degree of carbon-monoxide poisoning can vary greatly between individuals exposed to the same concentration of the CO in a confined area. Long before the CO reaches the flammable stage of 12.5 to 74 percent it is fatal. The work method used for measuring and monitoring CO are prone to errors as high as 35% which raises serious doubts on their reliance.

SUGGESTED PROCEDURES FOR TESTING MANHOLES AND UNDERGROUND STRUCTURES *Detailed records must be kept*

If the manhole cover is vented the first gas indicator tests should be done by inserting the non-sparking probe into the confined space through the vent hole. With no vent holes present, the cover should be pried open on the down wind side just enough to allow the test probe to be inserted. Care should be taken to avoid generation of friction sparks. This will test for lighter than air combustible gases.

Do not assume because the manhole was filled with water and had to be pumped dry that the atmosphere will be safe for entry. The removal of the water may remove the seals around ductlines etc. and permit unwanted gases to flow into the manhole from other areas. Test after pumping.

With the cover removed and from outside the manhole, test at the bottom as well as the openings for pipes, conduits or cables entering the structure.

A similar system of testing must be done to determine if the oxygen content is safe. The oxygen content must be between 18 and 23% to be safe.

When the atmosphere in the manhole is determined

to be free of combustible gas and has sufficient oxygen, check for a safe level of carbon monoxide.

If all tests are negative then it would appear safe to enter.

The worker entering the manhole should wear a life line and be attended by at least one worker on the surface prepared to remove him if necessary. The worker entering the confined space should be alert for any unusal odours or physical sensations which might indicate the presence of toxic vapour. If the work to be done requires the worker to remain underground, then continuous monitoring for both combustible vapours and oxygen deficiency must be done.

If combustible vapours below the lower explosive limit are detected, forced air ventilation should be used to clear the atmosphere. Steps should be taken to determine the source of the combustible gas. Be extremely careful to remove all sources of ignition.

If combustible vapours are detected above the explosive limit remember the forced air ventilation will reduce the gas concentration down to the explosive level before it is cleared.

Narrow trenches should be shored or dug back to the angle of natural repose for the soil, to prevent burial by the bulk material.

Attempts should be made to free the entrance of any material that would restrict your need for a sudden evacuation. Secure portable ladders so they remain firm and steady with rapid movement on them.

The following is an extract from the London PUC safety guidelines for entering manholes.

801 UNDERGROUND MANHOLES

1. Care shall be taken in removing manhole covers to prevent foot injuries. The proper lifting bar shall be used to remove manhole covers. Covers shall have the necessary square holes in order that the proper lifting bar can be used. Arrangements shall be made to have any cover found in service without square holes properly drilled.

2. Workmen shall not enter manholes until approved tests indicate the atmosphere safe for work and free from dangerous gases. If it is found by test that the atmosphere is unsafe due to presence of dangerous gas or lack of oxygen, the manhole shall be adequately and continuously ventilated while workmen are required to be in the manhole.

3. Lighted cigarettes, cigars, or pipes, or open flames that are not required for the work sh all not be taken into manholes even though tests indicate the atmosphere to be free from gas.

NOTE! When it is absolutely necessary to use an open flame such as a torch to peform the work, it shall only be done under the direct supervision of the man-in-charge.

4. If at any time, irritation of the eyes, nose or throat, difficulty in breathing, or a ringing sensation in the ears is experienced, workmen shall leave the manhole at once. They shall not return until it is thoroughly

ventilated and tests prove it to begas free.

5. An approved guard shall be erected around the manhole opening immdiately after the cover has been removed regardless of the length of time the manhole is to be open.

6. Workmen shall always use a ladder to enter or leave the manhole. Using racks or other equipment as steps is prohibited. When men are working in a manhole, the ladder shall not be removed unless it interferes with work. If the ladder is removed, it shall be kept at hand ready to drop into the hole and a workman shall be stationed at the surface close to the manhole to replace the ladder when required.

7. No more men shall be permitted in the manhole than are absolutely necessary to perform the work.

8. Tools and material shall not be left on the ground around the manhole opening where they might fall or be pushed into the hole.

9. Materials or tools shall not be thrown into or out of the manhole.

10. Fire pots shall be kept far enough from the manhole opening so that there will be no chance of hot metal or compound spilling into the hole in the event of the fire pot being overturned.

11. The practice of mixing run-off solder with molten solder within the manhole shall be kept to a minimum because of the fire hazard.

12. Employees shall at all times exercise every precaution to avoid work methods which might result in sparks or open flame.

13. Only ladders of non-conducting material shall be used except in permanent installations.

14. Employees shall not work alone when entry is made to a manhole or vault.

15. Employees shall not be present in manholes or underground vaults when equipment is being energized. Manholes and vaults shall not be entered until 4 hours after new or re-arranged equipment has been energized.

16. Where permissible and practicable, the vehicle shall be placed to guard the open manhole against oncoming traffic, securely braked, with the engine shut off, warning lights flashing and the ignition key removed.

    NOTE! Care shall be taken to avoid drain of exhaust gases from vehicles, generators and pumps into manholes.

17. After a manhole has been cleared of water which covers the ducts entering the manhole. the manhole shall be retested to ascertain whether gas is entering through the ducts.

18. If a tent is used over a manhole, atmospheric tests shall be conducted at intervals of not more than two hours.

19. All employees shall keep out of manholes and vaults while cables are being pulled (except

for training into position when necessary) when there is a tension on the pulling cable or rope.

20. Furnaces and tanks containing liquified petroleum gas, such as butane or propane, shall not be used or stored in a manhole, underground vault, or tent covering a manhole or vault.

21. Each underground crew, working in manholes, shall be equipped with a fire extinguisher, which shall be kept in operating condition and on the job at all times.

    NOTE! CO_2 extinguishers suffocate a fire with Carbon Dioxide gas. In confined spaces, this same gas can suffocate the operator of the extinguisher.

802 MANHOLE AND VAULT TESTING

1. The testing equipment shall not be operated when the batteries are so low that the voltmeter cannot be adjusted to the arrow.

2. The instrument shall be flushed with fresh air following completion of a test.

3. The equipment shall be tested for response prior to each test.

4. Any questionable atmosphere shall be tested from the outside first.

5. The sampling hose or probe shall not be allowed to reach into a liquid.

6. The instrument shall not be used for sampling gasoline vapours containing Tetra Ethyl lead unless it is specifically manufactured for that use.

7. Sampling hose fittings shall be checked for tightness prior to each test.

8. Samples shall not be taken from elevated temperatures into a cold instrument. Condensation may occur and give a false reading. Whenever possible, the instrument shall be at the same temperature of the vapour being sampled.

9. The flashback arrestors shall not be removed from the equipment. They prevent the explosion which occurs in the combustion chamber from passing back to the mixture being sampled.

10. The equipment shall be handled with care. Careless dropping of the instrument might very easily bend or distort the fine coils of these sensing elements, thus upsetting the calibration of the instrument.

SUMMARY

Suggestions for Improving Safety in Public Utility Operations are:

1. Develop a system safety approach to analyse all phases of your operation for hidden hazards.

2. Provide ventilation holes in the covers of all underground structures.

3. Education of supervisors in atmospheric hazards.

4. Education of employees in safe operation procedures.

5. Provide the proper instruments for the detection of atmospheric hazards.

6. Training of employees in the proper operation and maintenance of their necessary instruments.

7. Institute a regular inspection and record the results of testing of confined spaces. Report all abnormalities to supervision and the proper authorities.

8. Conduct an annual audit of all procedrues training programmes, instrumentation and records employed to reduce exposure to employees and the public from atmospheric hazards.

AIR PACKS

The-15 minute "Sac Pac" Air Pack

This unit should be put on and operational in 12-18 seconds.

To Put On

1. All straps to be fully extended and the pack hanging on the wall by the metal grummet.
2. Grasp air regulating valve facing you and turn on at least one complete turn.
3. Place the air pack on your back by placing your left arm through the left shoulder strap, then the right arm through the right shoulder strap.
4. Adjust the two adjusting straps at your shoulders to set pack comfortably on your back.
5. Reach around with your right hand and open pouch (pocket) on the bottom of the pack and the face mask will drop out.
6. With left hand grasp face mask and put harness of mask to the back of head, pull mask down over face placing your chin in the recessed area just below the full face screen.
7. Adjust head straps starting from the bottom upwards to the top of the head; always adjust both head straps on each side of the head at the same time to guarantee centering of mask over face.

   YOU ARE NOW BREATHING FRESH AIR.

The 15-minute "Sac Pac" Air Pack is only an emergency unit and does not come with a low air pressure alarm, however an alarm can be obtained if desired.

To Remove Unit

1. Remove face mask.
2. Fully extend (spiders) head straps.
3. Remove pack from your back.
4. Fully extend shoulder straps.
5. Shut off air regulator valve and purge the air line with the by-pass button located on the face mask.
6. Replace face mask into the pouch with the by-pass button facing upwards and the full face screen facing outwards so the head straps are to the base of the air pack.
7. Close flap.
8. Place the air pack back on the wall on the grummet.

Always refill the air cylinders after every use.

The 30-Minute Air Pack

This unit will usually take at least 2 minutes to put on. It is a working unit as well as an emergency unit.

On the harness pressure guage the "Red By-Pass" valve must be closed and the "Yellow Demand" valve locked open at all times.

To Put On

1. Ensure that all straps are extended.
2. Place air pack on back by placing left arm through left shoulder strap, then right arm through right strap. This should be done with your body slightly leaning forward to prevent air cylinder bottle from hitting your head. This also takes some of the weight off your shoulders.

3. Buckle the chest and waist belts and adjust pack to the most comfortable position on your back by the two small straps at your shoulders in front.

4. Fully open the air cylinder valve at the base of the cylinder. The harness pressure gauge should now read the cylinders air pressure.

5. Place face mask harness to the back of your head, pull mask down over your face placing your chin in the recessed area just below the full face screen.

6. Adjust head straps starting from the bottom upwards to the top of the head; always adjust both head straps on each side of the head at the same time to guarantee centering of the mask over the face.

7. Test face mask for air tightness by placing hand over hose end and taking a deep breath. If mask draws in around face, air tightness has been obtained.

8. Insert the hose end into the hole on the chest air gauge housing and hand tighten locking nut.

Air pack is now working.

A low air pressure alarm is activated when approximately 300 to 500 lbs. of air is left in cylinder. When alarm sounds, leave contaminated area immediately.

<u>To Remove Unit</u>

1. Remove procedure, shut off air cylinder valve, purge the system of air by opening red by-pass valve and then reclose it.

2. Extend all straps fully and replace air pack into holding case.

Always refill air cylinder after every time used.

The 20-Minute Air Pack

This unit is put on over the head and rests on the right shoulder with the cylinder valve at the left hip. All other procedures are the same as the 30-minute air pack.

All air packs must have the by-pass valve shut off except when:

1. *purging system after use*
2. *demand valve fails*
3. *face mask leaks around eye glasses side frames*
4. *full face screen is fogging up.*

All air packs pressure gauges to be checked monthly to see that air cylinders are full and the air cylinders to be hydro-static tested every five years.

Canister-Type Gas Masks

Many operators of water and wastewater treatment plants are still using canister-type gas masks for protection when a chlorine leak occurs. This type of mask provides only limited protection, even under ideal conditions.

The canister contains activated carbon and filters out chlorine gas in the air by absorption.

Each time it is used in the contaminated air, its absorption capacity is reduced.

The number of times it can be used before the carbon becomes exhausted is not known.

Warning:

A canister type mask will give no protection when the oxygen in the air is too low to support life, whether it is brand new or used only once. The Ontario Ministry of the Environment has replaced all canister type masks with small, self-contained air packs.

FIRST AID

1. Remove patient from gas area. Patient should be kept in a warm room (about 21°C). Supply blankets under and over patient. Keep patient warm and quiet. Rest is essential.

2. Place patient on back. Place a folded coat, blanket, etc., under victim's shoulders so his head falls well back. This maintains a clear air passage to lungs of victim.

3. Call for medical aid immediately.

4. Promptly remove clothing contaminated with liquid chlorine, or chlorinated water. Keep patient warm with blankets.

5. A mixture of carbon dioxide and oxygen, with no more than 7% carbon dioxide, may be given. This mixture, already prepared and sold with the necessary apparatus, can be administered for periods of two minutes followed by two-minute rest periods for no longer than thirty minutes. Follow instructions of the gas apparatus supplier carefully. If carbon dioxide and oxygen mixture is not readily available, then oxygen alone may be used, or fresh air "Air Pack".

6. Milk may be given in mild cases as a relief from throat irritation.

7. If breathing seems to have stopped, immediately start "Mouth to Mouth" or "Revised Sylvester" methods of artificial respiration. *Do not exceed 17 to 18 movements per minute.* If possible, assist respiration with an inhalator or respirator. See page 6-23.

8. When eyes are irritated with chlorine, wash repeatedly with water and then with 1% boracic acid solution. Castor or olive oil drops may be used. In severe cases of eye contamination due

to chlorine, use bubbler fountain, hose, or eye cup. Irrigate for 15 minutes. A routine of 5 minutes irrigation and 10 minutes rest should then be followed for one hour. Prompt action is absolutely essential to protect eyesight.

9. Areas of the skin which have been splashed with liquid chlorine or chlorinated water should be repeatedly washed with water. After thorough washing, any burned area should be covered with a sterile dressing and bandaged snugly unless blisters are apparent; then bandage loosely.

If facilities are available, it is generally recommended that patients be removed to hospital as soon as possible, unless recovery from chlorine exposure is prompt and the exposure mild.

REVISED SYLVESTER METHOD OF ARTIFICIAL RESPIRATION

Lose no time in starting - delay can be fatal.

1. Clear mouth of any obstructions.
2. Lay casualty on his back.
3. Elevate shoulders of casualty with a folded coat, blanket, etc., so his head falls well back. This maintains a clear air passage to his lungs.
4. Place casualty's head between your knees and grasp his arms at the wrist.
5. Cross arms over the lower half of the breastbone and rocking forward, press firmly downwards (about 20 lbs. pressure), forcing air out of lungs of casualty.
6. Release the pressure by rocking back and pull his arms upwards, outwards and backwards. This extends the chest walls and draws air into the casualty's lungs.

7. Repeat cycle 12 to 15 times per minute until doctor arrives and says to stop, or until normal breathing is restored, or rigor mortis has set in.

ORAL RESUSCITATION

Lose no time in starting - delay can be fatal.

1. Clear mouth of any obstructions.
2. Lay casualty on his back.
3. Place a folded coat, blanket, etc., under victim's shoulders so his head falls well back. This maintains a clear air passage to his lungs.
4. Kneel beside casualty's head.
5. Pinch his nose and open your mouth wide and blow into his mouth strongly enough to cause the casualty's chest to rise.
6. Remove your mouth. Casualty's chest should fall.
7. Repeat cycle 12 to 15 times per minute until doctor arrives and says to stop, or normal breathing is restored, or rigor mortis has set in.

Artificial respiration must be continued until natural breathing is restored, a doctor says to stop, or rigor mortis sets in.

PERSONAL HYGIENE

For the sake of your health and the health of your family:

1. Never eat your lunch or put anything into your mouth without first washing your hands.
2. Do not smoke while working in tanks, on pumps, trucks, filters, etc. Remember, you inhale or ingest the filth that collects on the cigarette from dirty hands. Save your smoking time for lunch hours or at home.
3. Never put your hands above your collar when working on any plant equipment, if possible.
4. Don't wear your overalls or rubber boots to the dining area.
5. Always wear your rubber boots when working in tanks, around sludge, washing down, etc. Don't wear your street shoes.
6. Keep your street shoes in your locker. Remember: what your shoes pick up at the plant they will leave on the floor of your home.
7. Don't wear your coveralls or rubber boots in your car or home.
8. Have a complete change of clothing to wear when going home.
9. Always clean any equipment such as safety belts, harness, face masks, gloves, etc., after using. You or someone else may want to use it again.
10. Always wear rubber or plastic coated gloves when cleaning out pumps, handling hoses, or when working around the plant.
11. Avoid putting on gloves when your hands are dirty. Wash first.

12. Wash with plenty of water or take a shower immediately after being splashed with sludge, or any chemical. *DON'T DELAY.*

13. Don't just wash your hands before going home. Wash your face thoroughly too. There is more of your face to carry germs than there is of your hands.

14. Wear a hat when working around sludge tanks, filters, or cleaning out grit or other channels. Don't go home with your head resembling a mop that just wiped up the floor around a cleaned out pump.

15. Keep your fingernails cut short and clean - they are excellent carrying places for dirt and germs.

APPENDIX E

SAFETY FROM ELECTRIC HAZARDS FOR WATER WORKERS

Learning to be a specialist in a trade requires some knowledge of many other trades, Often when more than one trade is combined on a project with other trades the various tradesmen work "hand and glove" together in the same environment and share job hazards. Exterior workers are exposed to many hazards of the construction industry. Interior workers are exposed to hazards of a factory environment.

The waterworks employee covers all these circumstances. He could be laying pipe outside or developing supply lines or indoor metering or material handling etc. He must become a specialist in his business. To be a specialist he must be aware of all the hazards of his work plus the hazards of the other trades he comes in contact with on the job. To work safely the waterworks employee must develop alertness. He must use his senses and powers of observation and of course good judgement in his work procedures.

No man can be classed as an expert or a specialist until he becomes efficient in his work. No man can be efficient until he performs safely. Efficiency and safety are synonymous in labour.

When it comes to electricity, working near it or working with it, a good rule of thumb to follow is:

If you don't know - don't.

If in doubt - ask.

Electricity is a subject one must not learn by contact. If the waterworks employee lives through the experience of an electrical contact he still might not have learned what happened or how to prevent a repeat injury. Electricity cannot be seen. Only its effects, heat, light, and motion, can be seen and felt.

When the waterworks employee looks at an electrical circuit he thinks of the conductor as a pipe, the voltage as water pressure, the amperage as gallons and the resistance as resistance to flow. This anology is close enough to explain how an electrical circuit works if one relates it to an enclosed hydraulic system.

The amperage flows out under pressure, does the work, and returns to the source.

Just as a high hydraulic pressure can rupture a pipe and allow the water to escape, so can a high voltage cause the electrical insulation to break down and the amperes to escape.

With knowledge of the properties of electricity, it can be forced along certain paths, perform its functions, and return to the source safely. Electricity is a reluctant servant and if it can take a short-cut and return to its source without doing its work it will do so. This is the danger of electricity. It always takes the easiest path back to the source.

If a person is in a position of being the easiest path back to the source then that person can be killed or injured. To the layman, the size of the conductor and the number of volts in the system are the dangers. To the knowledgeable person the current or amperage is the recognized killer. Individuals have been killed by as littls as 42 volts, direct current, and 0.06 amperes (60 milliamperes). The real measure of the electrical shock intensity

lies in the amount of current (amperes) forced through the body, not the voltage.

To give you some idea of the current quantity the amount of current necessary to light an ordinary household 100 watt light bulb is 0.85 amperes or 850 milliamperes. Current flows of 0.1 amperes to 0.2 amperes through the body are lethal. At values just below 0.1 ampere, breathing ceases and ventricular fibrillation of the heart occurs - an uncontrollable twitching of the walls of the heart ventricles. This heart flutter is most difficult to stop in the short interval of time between the shock and death. At values over 0.2 amperes the muscular contractions are so severe the heart is forcibly clamped during the shock. The belief is this clamping of the heart and then releasing when the shock is over more readily permits the victim to respond to artificial resuscitation.

<u>When working around electrical equipment, move slowly and surely with constant attention to balance and footing. Don't fool with it or experiment with it</u>.

Some PUCs such as London PUC use the pipeline system as part of the electrical circuit back to the source of power. This permits a better and more equal voltage regulation in the city. The waterworks employee may find in certain areas of the municipality large copper conductors connected to the water mains. These conductors must never be disconnected or parted without notifying the electrical department. They are harmless while connected to the water main and the electrical current travels through them back to its source through pipe and the soil. The voltage is zero while connnected, but, if parted, the voltage in a twinkling becomes whatever the voltage is on the circuit it is part of. If a person or object is between the parted ends of the conductor and if the voltage (electrical pressure) is high enough to force the current across the gap, it will do so, possibly with serious consequences to the employee or tool in the path across between the two ends of the parted conductor.

A similar situation is found at water meter installations. The household electrical system has two parallel return paths for the electrical service to the home. One of the parallel paths is through the metal conductors feeding the home, the other path is through the home plumbing out through the water meter to the soil or earth and back to the electrical source.

What does happen, is the household electrical wire connections are broken, weakened or corroded by age, weather, falling limbs etc. and the only remaining path of the circuit is back through the water meter.

To prevent the worker from becoming part of the household electrical circuit when changing water meters an electrical jumper wire must be put across the meter plumbing before attempting to remove the water meter. This is a safe procedure providing the jumper wire is as large as the electrical conductors feeding the home and providing the two connections of the jumper wire are made to bare, clean metal piping. Even a thin coat of paint or rust could increase the resistance to the electricity and cuase it to look for an easier path back to the source. Don't let that path be through you to the earth or to the incoming water service pipe.

Another electrical piece of equipment used by waterworks employees is the extension cord. These are temporary in nature and must never be installed for permanent use. The extension cord must be kept in good condition. This can be done by regular inspections. Always examine electrical equipment before using it. Electric extension cords; like gasoline, another hazard, are so common place that they are taken for granted.

Here are some recommendations for safe use of extension cords:

1. Make sure all connections are tight and the wire strands are held firmly under the screws.

2. Inspect closely for frayed, broken or brittle insulation.

3. Don't:
   a. place cords near sources of heat such as the light bulb on the end;
   b. knot or hang from nails;
   c. trail cords through oil and water unless they are specifically labelled for use in these substances;
   d. electrically overload the cord.

4. Use a three wire grounded cord; always remove it from the receptacle by standing in a dry area with the right hand on the plug and the left hand not touching anything else.

Just a few words on fuses. Whenever a fuse blows in an electrical circuit become suspicious of the safe condition of the circuit. What caused the fuse to blow? Overload? Breakdown of insulation? Don't stop your questioning until you have a reasonable answer. A fuse will blow when the electrical current flowing through it exceeds the safe limits the system was designed for.

Whenever electrically driven power tools are used the tools must be grounded through a three wire system to the tool itself. Never use a power tool while standing on wet or damp surfaces. The insulation or the green ground wire could or has failed and the operator can become the easiest path back to the source of for the electricity.

A recent development is the double-insulated power tool supplied by a two wire cord. These double-insulated

tools must be approved by the C.S.A. - Canadian Standard Association. All tools must be examined before use.

Never use power tools in an atmosphere where there is hazard of flammable explosive vapours, gases or dusts unless they are approved vapour-proof tools. The reasons are obvious.

Electrical injury to man is related to the intensity and duration of the current flow through the human body. There is a device called a Ground-Fault-Circuit-Interrupter (GFCI) that can be incorporated into an electrical circuit for personnel protection against hazardous shock. This is a current sensing device which continuously monitors the current flow in both wires of the circuit. Whenever an imbalance develops between the wires greater than 5 milliamperes the built in circuit breaker trips and stops the flow of current in the circuit in 1/40 of a second. You can readily see how this G.F.C.I. could reduce the length of time and quantity of current flow through the human body.

There are two types of G.F.C.I. The one described above and another with a higher trip value for equipment protection. They come in sizes to suit the need. The physical size of the smaller unit permits it to plug into a standard electrical receptacle and then you plug the extension cord into it. The G.F.C.I. unit will trip whenever a part of the circuit insulation breaks down and the current leaks to ground, such as a faulty drill motor leaking to ground through the operator.

Another grave type of hazard that causes many deaths in any year are overhead wires at or near work sites. Electric wires and pole lines are so common a sight to us that after a time they become invisible. The construction worker operating equipment that can raise or lift to height of electrical conductors must never forget to check for safe

clearance before raising or lifting the dump-box, crane, boom, forks or material load.

The operator of the equipment usually does not get hurt when the equipment contacts an energized appratus. It is the person standing on the ground who gets hurt. A fault current may exceed thousands of amperes when a crawler crane touches an electrical conductor. The electrical path through the machine may conduct 99.9% of the fault current to the ground, but, that remaining 0.1% is more than enough to kill a worker(s).

Always stand aside and never touch the equipment when it is digging or working in the vicinity of energized apparatus.

The Occupational Health and Safety Act, Part II Sections 100-105, clearly defines the safe limits of approach to power lines energized at over 750 volts.

Waterworks people are not familiar with electric line design and cannot readily tell hazardous voltage construction from harmless construction. Going back to the rule of thumb, "if you don't know - don't", get the information from the electrical supplier. Many, people are electrocuted on 120 volt (household voltage) electrical contacts. Treat all electric wires as lethal. Even a brush or scrape contact against energized conductors can kill. The hazardous electrical apparatus encroaching on the work site should be disconnected and grounded; or the apparatus insulated to prevent any electrical flow through workers and machines.

Always get locates from other utilities buried underground before beginning to work at excavating or trenching. Any services that might endanger the worker having access to the excavation shall be shut off and disconnected.

When it is necessary to break through the cover and overburden near underground circuits, ducts or concrete envelopes housing energized conductors the following precautions shall be observed if pneumatic or hydraulic tools are to be used:

1. The pneumatic or hydraulic tools shall be properly and adequately grounded.

2. Only approved types of non-conducting hose shall be used with pneumatic or hydraulic tools.

3. Suitable rubber protective devices, in the form of rubber gloves, rubber aprons, rubber platforms or rubber boots, shall be used.

The circuits that endanger the worker should be identified, disconnected, and grounded to prevent undue exposure to the worker, thus reducing the hazard of mechanical damage to the circuit by the excavating being undertaken.

There is no substitute for a knowledgeable worker. The skills he brings to the job must be augmented by the knowledge of the hazards present and the safe, proper work procedures needed to protect him.

When it comes to electrical hazards remember the rule of thumb:

If you don't know - DON'T

If in doubt - ASK

CHARACTERISTICS OF DANGEROUS GASES

GAS	CHEMICAL FORMULA	COMMON PROPERTIES*	SPECIFIC GRAVITY OR VAPOUR DENSITY (AIR=1)	PHYSIOLOGICAL EFFECT*	MAX SAFE 60-MIN EXPOSURE (% BY VOL. IN AIR)	MAX SAFE 8-HR EXPOSURE (% BY VOL. IN AIR)	EXPLOSIVE RANGE (% BY VOL. IN AIR) LOWER LIMIT	UPPER LIMIT	LIKELY LOCATION OF HIGHEST CONCENTRATION	MOST COMMON SOURCES
CARBON DIOXIDE	CO_2	COLORLESS, ODORLESS WHEN BREATHED IN LARGE QUANTITIES MAY CAUSE ACID TASTE. NONFLAMMABLE. NOT GENERALLY PRESENT IN DANGEROUS AMOUNTS UNLESS O_2 DEFICIENCY	1.53	CANNOT BE ENDURED AT 10% MORE THAN FEW MIN, EVEN IF SUBJECT IS AT REST AND OXYGEN CONTENT NORMAL. ACTS ON RESPIRATORY NERVES.	4 TO 6	0.5	-	-	AT BOTTOM; WHEN HEATED MAY STRATIFY AT POINTS ABOVE BOTTOM	PRODUCTS OF COMBUSTION, SEWER GAS, SLUDGE. ALSO ISSUES FROM CARBONACEOUS STRATA.
CARBON MONOXIDE	CO	COLORLESS, ODORLESS, TASTELESS, FLAMMABLE, POISONOUS.	0.97	COMBINES WITH HEMOGLOBIN OF BLOOD. UNCONSCIOUSNESS IN 30 MIN AT 0.2 TO 0.25%. FATAL IN 4 HR AT 0.1%. HEADACHE IN FEW HR AT 0.02%	0.04	0.01	12.5	70.0	NEAR TOP, ESPECIALLY IF PRESENT WITH ILLUMINATING GAS.	MANUFACTURED GAS, FLUE GAS, PRODUCTS OF COMBUSTION, MOTOR EXHAUST, FIRES OF ALMOST ANY KIND.
GASOLINE	C_5H_{12} TO C_9H_{20}	COLORLESS, ODOR NOTICEABLE AT 0.03% FLAMMABLE.	3.0 TO 4.0	ANESTHETIC EFFECTS WHEN INHALED. RAPIDLY FATAL AT 2.4%. DANGEROUS FOR SHORT EXPOSURE AT 1.1 TO 2.2%.	0.4 TO 0.7	0.10	1.3	6.0	AT BOTTOM	SERVICE STATIONS, GARAGES, STORAGE TANKS, AND HOUSES.
HYDROGEN	H_2	COLORLESS, ODORLESS, TASTELESS. FLAMMABLE.	0.07	ACTS MECHANICALLY TO DEPRIVE TISSUES OF OXYGEN. DOES NOT SUPPORT LIFE.	-	-	4.0	74.0	AT TOP.	MANUFACTURED GAS, SLUDGE DIGESTION TANK GAS, ELECTROLYSIS OF WATER. RARELY FROM ROCK STRATA.

* PERCENTAGES SHOWN REPRESENT VOLUME OF GAS IN AIR.

CHARACTERISTICS OF DANGEROUS GASES (Cont'd)

GAS	CHEMICAL FORMULA	COMMON PROPERTIES*	SPECIFIC GRAVITY OR VAPOUR DENSITY	PHYSIOLOGICAL EFFECT *	MAX SAFE 60-MIN EXPOSURE (% BY VOL. IN AIR)	MAX SAFE 8-HR EXPOSURE (% BY VOL. IN AIR)	EXPLOSIVE RANGE (% BY VOL. IN AIR) LOWER LIMIT	UPPER LIMIT	LIKELY LOCATION OF HIGHEST CONCENTRATION	MOST COMMON SOURCES
HYDROGEN SULFIDE	H_2S	ROTTEN EGG ODOR IN SMALL CONC. EXPOSURE FOR 2 TO 5 MIN AT 0.01% IMPAIRS SENSE OF SMELL. ODOR NOT EVIDENT AT HIGH CONC. COLORLESS. FLAMMABLE.	1.19	IMPAIRS SENSE OF SMELL RAPIDLY AS CONC. INCREASES. DEATH IN FEW MIN AT 0.2% EXPOSURE TO 0.07 TO 0.1% RAPIDLY CAUSES ACUTE POISONING. PARALYZES RESPIRATORY CENTER.	0.02	0.002	4.3	46.0	NEAR BOTTOM, BUT MAY BE ABOVE BOTTOM IF AIR IS HEATED & HIGHLY HUMID.	COAL GAS, PETROLEUM SEWER GAS. FUMES FROM BLASTING UNDER SOME CONDITIONS SLUDGE GAS.
METHANE	CH_4	COLORLESS, ODORLESS, TASTELESS. FLAMMABLE	0.55	ACTS MECHANICALLY TO DEPRIVE TISSUES OF OXYGEN. DOES NOT SUPPORT LIFE.	PROBABLY NO LIMIT PROVIDED OXYGEN PERCENTAGE IS SUFFICIENT FOR LIFE.		5.0	15.0	AT TOP, INCREASING TO CERTAIN DEPTH.	NATURAL GAS, SLUDGE GAS, MANUFACTURED GAS, SEWER GAS. STRATA OF SEDIMENTARY ORIGIN. IN SWAMPS OR MARSHES.
NITROGEN	N_2	COLORLESS, TASTELESS. NONFLAMMABLE. PRINCIPAL CONSTITUENT OF AIR (ABOUT 79%).	0.97	PHYSIOLOGICALLY INERT	-	-	-	-	NEAR TOP, BUT MAY BE FOUND NEAR BOTTOM.	SEWER GAS, SLUDGE GAS. ALSO ISSUES FROM SOME ROCK STRATA.
OXYGEN (IN AIR)	O_2	COLORLESS, ODORLESS,	1.11	NORMAL AIR CONTAINS 20.93% OF O_2. MAN CAN TOLERATE DOWN TO 12% MIN SAFE 8-HR EXPOSURE, 14 TO 16%. BELOW 10% DANGEROUS TO LIFE. BELOW 5 TO 7% PROBABLY FATAL.	-	-	-	-	VARIABLE AT DIFFERENT LEVELS.	OXYGEN DEPLETION FROM POOR VENTILATION AND ABSORPTION, OR CHEMICAL CONSUMPTION OF OXYGEN.
SLUDGE GAS	-	MAY BE PRACTICALLY ODORLESS, COLORLESS.	VARIABLE	WILL NOT SUPPORT LIFE.	NO DATA. WOULD VARY WIDELY WITH COMPOSITION.	-	5.3	19.3	NEAR TOP OF STRUCTURE.	FROM DIGESTION OF SLUDGE.

CHARACTERISTICS OF GAS FUELS

GAS	CHEMICAL FORMULA	B. T. U. CALORIFIC VALVE	SPECIFIC GRAVITY OR VAPOUR DENSITY	EXPLOSIVE LIMITS IN AIR % BY VOLUME		THEORECTICAL AIR REQUIRED FOR COMPLETE COMBUSTION	MINIMUM IGNITION TEMPERATURE °FAHRENHEIT	MAXIMUM FLAME TEMPERATURE °FAHRENHEIT	FLAME SPEED PER SEC.	AUTO IGNITION TEMPERATURE
				LOWER	UPPER					
METHANE	CH_4	913.1	0.55	5	15	9.56 TO 1	1170°	3484°	0.85	1000
NATURAL GAS		1027	0.6	4.9	15	10.00 TO 1	1170°	3562°	0.99	1000
PROPANE	C_3H_8	2385	1.52	2.10	10.10	23.9 TO 1	898°	3573°	0.95	871

SUBJECT: TOPIC: 11

WATER DISTRIBUTION SYSTEM MAINTENANCE

Leak Detection, and Fire Flow Testing

OBJECTIVES:

The trainee will be able to:

1. Recall the means employed to determine the hydraulic condition of a watermain and the benefits obtained.
2. Perform a leak detection survey.
3. Recall the requirements for fire protection.
4. Recall the purpose of flow testing from hydrants.
5. Perform a flow test from hydrants and the related calculation.

LEAK DETECTION

FIRE FLOW TESTING

INTRODUCTION

The functions of a municipal water distribution system are to provide a potable water supply for domestic and commercial usage and to supply water for fire protection. To satisfactorily fulfil these requirements, the water must be supplied at adequate pressure. These are extremely important requirements, but so often the system receives no maintenance other than to restore to service those parts of the system that have failed to perform adequately. This is not usually due to an indifferent attitude toward the system on the part of the maintenance engineer or superintendent, but rather due to a lack of knowledge or lack of established procedure or methods in the industry as to what should be done and in the case of recurring maintenance, at what intervals of time or usage this should be performed and of course to budget restriction. The issue is further complicated by the differences in the quality of the water in different areas and varying soil conditions even in the same area.

The maintenance functions can be grouped into two classes -

1. Those that keep the system in good operating order ready for emergency situations, such as valve and hydrant maintenance.

2. Those that reduce wastage or increase revenue, such as leak detection surveys and meter maintenance.

Maintenance of any nature costs money to perform initially whether an ultimate cost benefit is achieved or not. A maintenance program in any area must however be complete to be worthwhile. For example, there is no point in having a valve or hydrant inspection program unless it is followed up with correction of any unsatisfactory condition noted.

LEAK DETECTION

General

An external examination of a water main is in most cases only possible by excavating down to and around the sides of the main and completely exposing the joints. This procedure would be almost as costly or possibly even more costly than replacing the main and is therefore totally impractical. One should also keep in mind that by exposing a main in this manner, the natural bedding of the pipe is distributed and in the long run more harm than good may result.

Internal examination of mains as small as six-inch diameter by T.V. camera is not yet possible. However, even if it were possible, a T.V. camera would not indicate a leak at a joint and the definition of the picture would not be sufficient to disclose cracks in a pipe.

The *hydraulic condition* of a main or group of mains can be determined by means of a group of tests:

1. Leak Detection Surveys.
2. Fire Flow Tests.
3. Loss of Head Tests.

Leak Detection Surveys

There are two methods of carrying out leak detection surveys, namely the sounding method and the Pitometer method.

1. Sounding Method

The sounding method is exactly as its name implies. Special listening devices designed to filter out spurious sounds and to amplify the sound of escaping water are used to listen for leaks in the system. They may be placed in contact with some part of the system such as a fire hydrant, valve or a curb stop box or they might be placed on the pavement.

2. Pitometer Surveys

Pitometer surveys are conducted by isolating a section of distribution system so that all water is entering the area through a minimum number of points. Pressure gauges are installed within the area and are read as the valves are being closed to ensure that the pressure is not being unduly reduced. At the point or points where the water is entering the district, pitometers are installed to measure the water entering the district. The theoretical amount of water being used in the district is calculated. This is done by:

a. Assuming that those consumers on flat rate are using the amount of water for which they are paying.

b. Taking actual meter readings, over a twenty-four hour period, of large metered consumers.

c. Taking daily averages of corresponding previous billing periods for lesser metered consumers.

A comparison is made between the measured consumption and the theoretical consumption and also between daytime rates of flow and night-time rates. If an undue rate seems to exist in the comparisons, leakage is suspected and the area is subdivided to isolate the general area in which the leak is situated. The leak is then pinpointed by listening devices.

The former method is much faster than the latter, but the Pitometer method has other side advantages.

1. Because operation of valves is necessary, valves which have been left closed are frequently encountered and opened.

2. A record of water consumption in the area being surveyed is obtained.

Loss of Head Test

Loss of head tests are performed by isolating a section of main so that it is fed from one end only. Water is discharged from a hydrant at a point nearest the closed valve and the volume of water being discharged is measured. Pressures are also read at two points ahead of discharge both with the hydrant open and with the hydrant closed.

The volume of water discharged may be determined by means of a pitot tube at the point of discharge or by a pitometer at the point of entry of the water into the main. If the latter method is used, readings on the pitometer should be made before and during the tests and adjustment made for the water used from the main by consumers. Measuring the volume of water at discharge does not take this

local consumption into account. Needless to say the pitometer method is more accurate.

From the formula

$$C = \left(\frac{Q}{(1.318, Ar.^{.63})S.^{.54}}\right).$$

Q	=	cfs
A	=	S.F.
r	=	ft. hydraulic radius
S	=	$\frac{ft}{ft}$

the value of "C" for the Hazen & Williams formula can be determined.

Loss of head tests indicate the actual carrying capacity of the main and give some indication of the degree of deterioration of its carrying capacity as a result of tuberculation.

Fire Flow Test

The fire flow test determines the amount of water available for fire protection under normal conditions and also with pumpers attached. It will also indicate to some extent what is available for normal usage at reduced pressures. These tests do not, however, normally indicate the condition of the mains. The test procedure is at Appendix A.

The standard established by the Insurer's Advisory Organization states in respect to pressure that, in water supply, the principal requirement considered is the ability to deliver water in sufficient quantity to permit pumpers of the Fire Department to obtain an adequate supply from hydrants. To overcome friction loss in the hydrant

branch, hydrant and suction hose, a minimum residual pressure of 20 p.s.i. on the street main is required during the flow. Higher sustained pressure is of importance in permitting direct supply to automatic sprinkler systems and building stand pipe and hose systems, and in maintaining a water plane such that no part of the protected area is without water.

A water supply system is considered to be adequate for fire protection when it can supply water as indicated above with consumption at the maximum daily rate. Certain types of emergency supplies may be included where reasonable conditions for their immediate use exist. Storage on the system is credited on the basis of the normal daily minimum maintained in so far as pressure permits its delivery at the rate considered.

Application of Test Results

As a result of these tests inadequacies in the system are determined and the necessary steps to correct them can then be undertaken. These corrective measures may consist of either constructing additional mains or, if the loss of head tests indicate deficiencies in the existing mains, of cleaning and cement mortar lining the existing mains to restore them to their original capacity. In some cases both steps might be necessary, that is, cleaning and lining the existing mains, and constructing additional mains.

FLOW TESTING FROM HYDRANTS

Flow testing from hydrants is required to determine how much water is obtainable during a fire emergency and to be reasonably sure that the quantity we measure will actually be available in such an event. The actual performance at a given point in the underground water main system depends on such factors as length size interconnections and age. Furthermore as flow increases the drag or friction loss also increases. Thus with increased flow there is always an accompanying decrease in the "residual" pressure.

Test Procedure

1. Purpose of Test. To discharge water from the flow hydrant at varying rates of discharge so as to determine the quantity of water available for fire protection for a building at the residual pressure, both readings being taken simultaneously.

2. Tools and Equipment Required.

    a. A pitot tube and accurate test gauge.
    b. A measure for determining the diameter of the discharging orifice.
    c. A hydrant cap with a "pet cock" or air bleed valve and provision for installing a test gauge.

d. A selection of nozzles, e.g. 1-1/8", 1-3/4", 2½ are common.

e. Hydrant wrenches and a small adjustable C-wrench for gauge removal.

f. Water Supply Test form including graph paper. (Annexure 1)

g. Discharge Tables for Smooth Nozzles. (Annexure 2).

H. Discharge Table for Circular Outlets (Annexure 3).

Note: If tables (g) and (h) are not available calculations must be made using the information at Appendix B.

3. Procedure

a. Determine which way the water in the main is flowing, if possible. In small mains this has more significance than in large mains.

b. Next, select two consecutive hydrants on the main. The upstream hydrant should be as close to the building as possible. The "upstream" hydrant will be the one from which the residual pressure readings and static readings can be taken on a sprinkler riser in the building provided there are no check valves between the gauge and the street main.

The next hydrant downstream or away from the water source (preferably past the building) is used as the "flow" hydrant. Take care that the hydrant can discharge safely away from doorways, driveways, lawns, vehicles or soil and ground that can be eroded. (Frequently these practical considerations

determine where the flow will be taken).

c. Open both hydrants to flush out stones, grease, antifreeze, etc.

d. Attach the hydrant cap and gauge to the residual hydrant, open the air bleed valve and open the hydrant. When water discharges from the air bleed valve, close it and read the "static" pressure. Record the static pressure on the "Water Supply Test Sheet".

Make sure that no pumps will cut in or out during the whole test. If they do, the results will be confusing. The usual procedure is to have the pumping station put on manual operation, all pumps that would normally cut in automatically on a high flow demand. Manually started pumps may also be started depending upon assessment of the individual situation.

NOTE: In small town or where the water supply is in any way doubtful, two tests should be taken. The first test will be to determine what will automatically be available and the second test will be with manually started pumps running to determine the total flow possible.

e. Have one man stand by the "residual" hydrant then have the "flow" hydrant, to which are attached one or two suitable nozzles, opened. At the same time by pre-arranged signal, have the other man read the residual pressure and write it down. Repeat this procedure using different size nozzles and/or varying the

"flow" hydrant setting so that a series of three or four sets of readings are taken simultaneously of the pitot and residual pressures. Pitot readings of less than 10 psi should be avoided since experience indicates that they are unreliable.

It is usually a good policy to flow as much water as possible and at least as much as is required, by the combined calculation sprinkler and hose demand, in order to obtain an as accurate result as possible.

f. Close the flowing hydrant slowly to avoid water hammer and possible rupture of pipes. Read the static pressure again as a check.

g. The results are then tabulated on the water flow test sheet and the gallons (U.S.) discharge read from the available flow tables. Use the pitot pressures to figure the amount discharged and be sure to get the correct nozzle diameter to the nearest 1/16".

h. Plot the results on the special graph paper on the back of the Water Supply Test form plotting gallons discharged against residual pressure. Draw a "straight line" through the points so as to cut through most. If they are widely separated, check the figures and possibly retest. If still not compatible, investigate pump operation and possible large "draw-offs" by neighbouring industries.

i. If the results are close to a straight line, the "residual" hydrant may be closed, but be sure the gauge is not subjected to a vacuum which could result in damage or at least the need for recalibration of the gauge.

INSURERS' ADVISORY ORGANIZATION OF CANADA

Example Only

APPENDIX B

WATER SUPPLY TEST

Name of risk: ABC Co. File No.: 1234

Address: 1001, Water St. Test by: XYZ

Municipality: UTOPIA Date: Feb 29/80

SYSTEM DATA:

Size of Main: 10 in. Dead End: ✓ Two Ways: Loop:

Source Reliable: YES If not explain:

Comments: New hydrant with sharp edges to outlet on inside

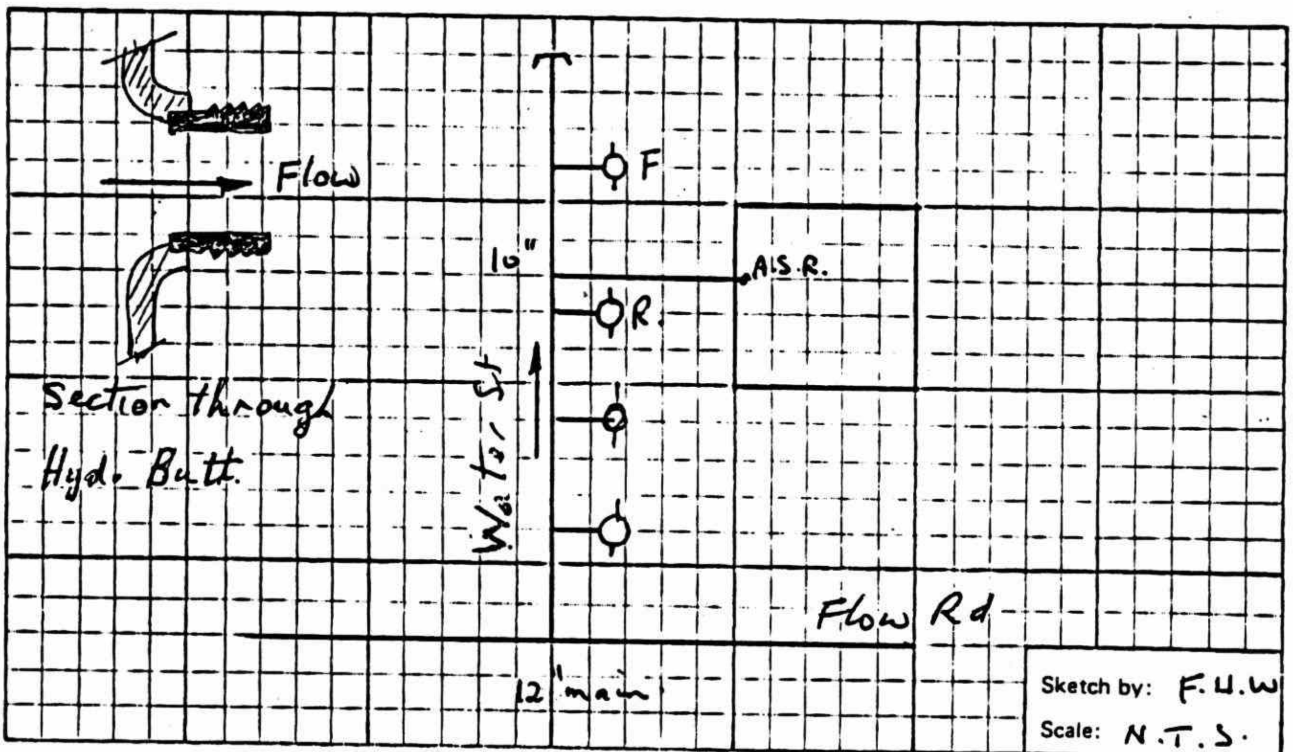
TEST DATA:

Location of test hydrants; Residual:

Flow:

Static pressure 80 psig. Time: 9.00 A.M. P.M.

Test No.	No. of Outlets	Orifice Size(in.)	Pitot Reading (psig)	Equivalent Flow gpm (U.S.)	Total Flow gpm (U.S.)	Residual Pressure (psig)	Comments
1	1	1 1/8	50	265	265	74	
2	1	1 3/4	40	575	575	69	
3	1	2 1/2 Tube	32	950	950	60	C = .9
4	2	2 1/2 Butts	28	2x890x.88	1566	41	Multiply by .88



Sketch by: F.U.W

Scale: N.T.S.

Name and address of municipal authority who should receive a copy.

P.U.C. River St. UTOPIA

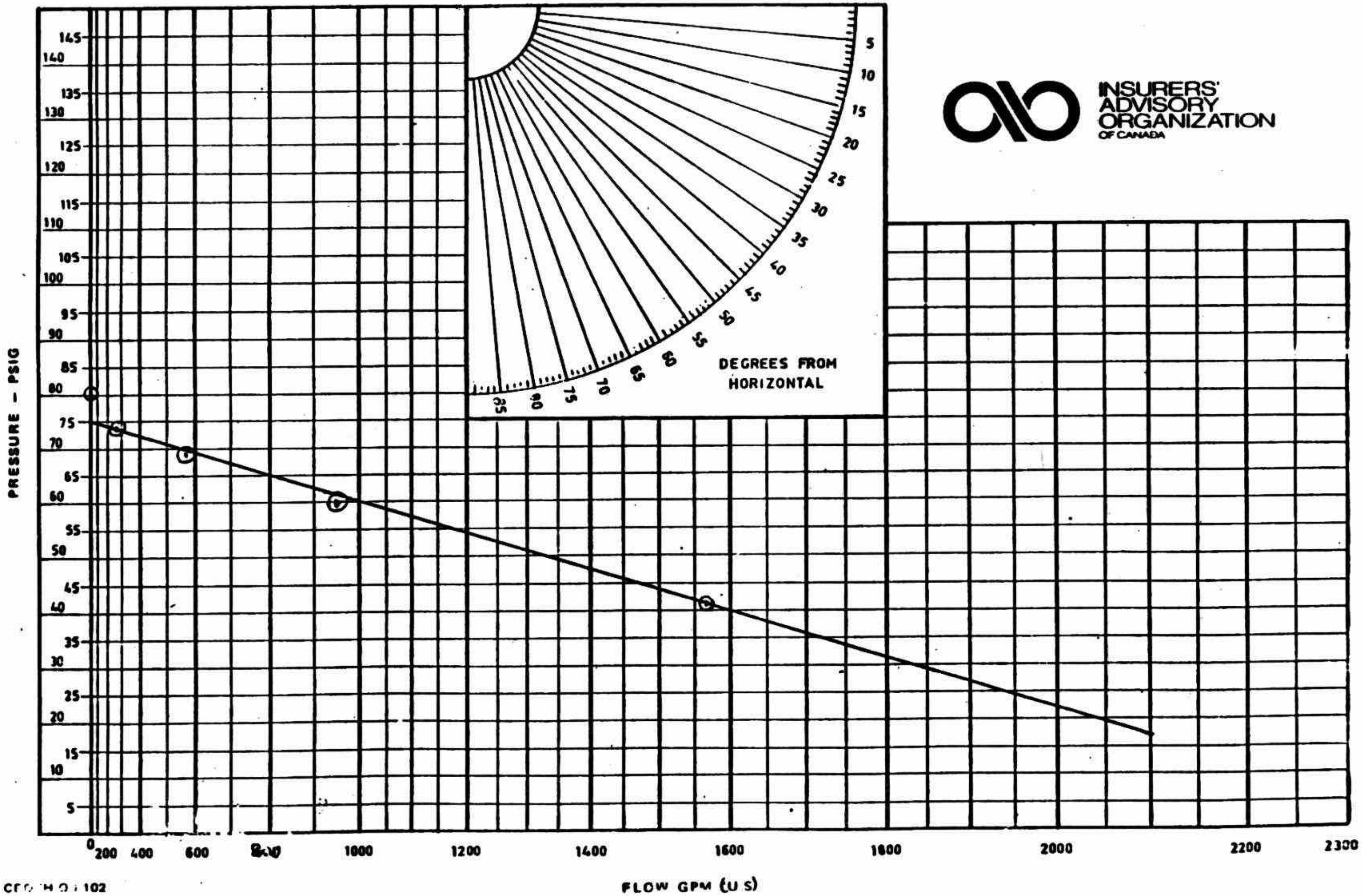
NAME OF RISK: ABC Co. FILE NO.: 1234

ADDRESS: 1001, Water St.

MUNICIPALITY: UTOPIA

DATE: Feb 29/80 BY: F.H.W.

INSURERS' ADVISORY ORGANIZATION OF CANADA



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ANNEXURE I

DISCHARGE TABLE FOR SMOOTH NOZZLES

NOZZLE PRESSURE MEASURED BY PITOT GAGE

Nozzle Pressure in lbs. per sq. inch	Nozzle Diam. in Inches 1/2	5/8	3/4	7/8	Nozzle Diam. in Inches 1	1 1/8	1 1/4	1 3/8	1 1/2	Nozzle Diam. in Inches 1 5/8	1 3/4	1 7/8	2	2 1/4	Nozzle Pressure in lbs. per sq. inch
	Gallons per Minute				Gallons per Minute					Gallons per Minute					
5	16	26	37	50	66	84	103	125	149	175	203	234	266	337	5
6	18	28	41	55	72	92	113	137	163	192	223	256	292	369	6
7	19	30	44	59	78	99	122	148	176	207	241	277	315	399	7
8	21	32	47	64	84	106	131	158	188	222	257	296	336	427	8
9	22	34	50	67	89	112	139	168	200	235	273	314	357	452	9
10	23	36	53	71	93	118	146	177	211	248	288	330	376	477	10
12	25	40	58	78	102	130	160	194	231	271	315	362	412	522	12
14	27	43	63	84	110	140	173	210	249	293	340	391	445	564	14
16	29	46	67	90	118	150	185	224	267	313	364	418	475	603	16
18	31	49	71	95	125	159	196	237	283	332	386	444	504	640	18
20	33	51	75	101	132	167	206	250	298	350	407	468	532	674	20
22	34	54	79	105	139	175	216	263	313	367	427	490	557	707	22
24	36	56	82	110	145	183	226	275	327	384	446	512	582	739	24
26	37	59	85	115	151	191	235	286	340	400	464	533	606	769	26
28	39	61	89	119	157	198	244	297	353	415	481	554	629	799	28
30	40	63	92	123	162	205	253	307	365	429	498	572	651	826	30
32	41	65	95	127	167	212	261	317	377	443	514	591	673	854	32
34	43	67	98	131	172	218	269	327	389	457	530	610	693	880	34
36	44	69	100	135	177	224	277	336	400	470	546	627	713	905	36
38	45	71	103	138	182	231	285	345	411	483	561	645	733	930	38
40	46	73	106	142	187	237	292	354	422	496	575	661	752	954	40
42	47	74	109	146	192	243	299	363	432	508	589	678	770	978	42
44	49	76	111	149	196	248	306	372	442	520	603	694	788	1000	44
46	50	78	114	152	200	254	313	380	452	531	617	710	806	1021	46
48	51	80	116	156	205	259	320	388	462	543	630	725	824	1043	48
50	52	81	118	159	209	265	326	396	472	554	643	740	841	1065	50
52	53	83	121	162	213	270	333	404	481	565	656	754	857	1087	52
54	54	84	123	165	217	275	339	412	490	576	668	769	873	1108	54
56	55	86	125	168	221	280	345	419	499	586	680	782	889	1129	56
58	56	87	128	171	225	285	351	426	508	596	692	796	905	1149	58
60	57	89	130	174	229	290	357	434	517	607	704	810	920	1167	60
62	58	90	132	177	233	295	363	441	525	617	716	823	936	1187	62
64	59	92	134	180	237	299	369	448	533	627	727	836	951	1206	64
66	60	93	136	182	240	304	375	455	542	636	738	850	965	1224	66
68	60	95	138	185	244	308	381	462	550	646	750	862	980	1242	68
70	61	96	140	188	247	313	386	469	558	655	761	875	994	1260	70
72	62	97	142	191	251	318	391	475	566	665	771	887	1008	1278	72
74	63	99	144	193	254	322	397	482	574	674	782	900	1023	1296	74
76	64	100	146	196	258	326	402	488	582	683	792	911	1036	1313	76
78	65	101	148	198	261	330	407	494	589	692	803	924	1050	1330	78
80	66	103	150	201	264	335	413	500	596	700	813	935	1063	1347	80
82	66	104	152	204	268	339	418	507	604	709	823	946	1076	1364	82
84	67	105	154	206	271	343	423	513	611	718	833	959	1089	1380	84
86	68	107	155	208	274	347	428	519	618	726	843	970	1102	1396	86
88	69	108	157	211	277	351	433	525	626	735	853	981	1115	1412	88
90	70	109	159	213	280	355	438	531	633	743	862	992	1128	1429	90
92	70	110	161	215	283	359	443	537	640	751	872	1002	1140	1445	92
94	71	111	162	218	286	363	447	543	647	759	881	1012	1152	1460	94
96	72	113	164	220	289	367	452	549	654	767	890	1022	1164	1476	96
98	73	114	166	223	292	370	456	554	660	775	900	1032	1176	1491	98
100	73	115	168	225	295	374	461	560	667	783	909	1043	1189	1506	100
105	75	118	172	230	303	383	473	574	683	803	932	1070	1218	1542	105
110	77	121	176	236	310	392	484	588	699	822	954	1095	1247	1579	110
115	79	123	180	241	317	401	495	600	715	840	975	1120	1275	1615	115
120	80	126	183	246	324	410	505	613	730	858	996	1144	1303	1649	120
125	82	129	187	251	331	418	516	626	745	876	1016	1168	1329	1683	125
130	84	131	191	256	337	427	526	638	760	893	1036	1191	1356	1717	130
135	85	134	195	262	343	435	536	650	775	910	1056	1213	1382	1750	135
140	87	136	198	266	350	443	546	662	789	927	1076	1235	1407	1780	140
145	88	139	202	271	356	450	556	674	803	944	1095	1257	1432	1812	145
150	90	141	205	275	362	458	565	686	817	960	1114	1279	1456	1843	150
	(C= .985)				(C= .99)					(C= .997)					

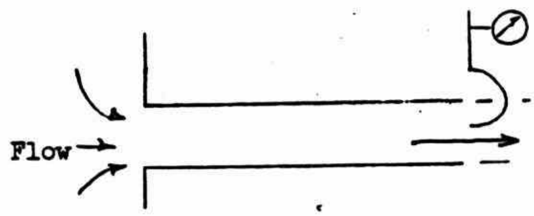
DISCHARGE TABLE FOR CIRCULAR OUTLETS*

Outlet Pressure Measured by Pitot Gauge

Outlet Pressure in lbs. per sq. inch	OUTLET DIAMETER IN INCHES											
	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/8	3 7/8	4	4 3/8	4 1/2	4 5/8
	U.S. Gallons Per Minute											
1	150	170	180	200	220	240	260	400	430	510	540	580
2	210	240	260	290	310	340	370	570	610	720	770	810
3	260	290	320	350	380	420	450	700	740	890	940	990
4	300	340	370	410	440	480	530	810	860	1030	1090	1150
5	340	380	410	450	500	540	590	900	960	1150	1220	1290
6	370	410	450	500	540	590	640	990	1050	1260	1340	1410
7	400	440	490	540	590	640	690	1070	1140	1360	1440	1520
8	430	480	520	570	630	680	740	1140	1220	1450	1540	1620
9	450	500	550	610	670	730	790	1210	1290	1540	1640	1720
10	480	530	580	640	700	760	830	1280	1360	1630	1730	1820
11	500	560	610	670	730	800	870	1340	1430	1710	1810	1910
12	520	580	640	700	770	840	910	1400	1490	1780	1890	1990
13	550	610	670	730	800	870	950	1450	1550	1850	1960	2070
14	570	630	690	760	830	900	980	1510	1610	1920	2040	2150
15	590	650	720	790	860	940	1020	1560	1660	1990	2110	2220
16	610	670	740	810	890	970	1050	1620	1720	2060	2180	2300
17	620	690	760	840	910	1000	1080	1680	1770	2120	2240	2370
18	640	710	780	860	940	1030	1110	1710	1820	2180	2310	2440
19	660	730	810	890	960	1050	1140	1760	1870	2240	2370	2510
20	680	750	830	910	990	1080	1170	1800	1920	2290	2430	2570
22	710	790	870	950	1040	1130	1230	1890	2020	2400	2550	2700
24	740	820	910	1000	1090	1180	1290	1970	2110	2510	2660	2810
26	770	860	940	1040	1130	1230	1340	2050	2190	2620	2770	2930
28	800	890	980	1070	1170	1280	1390	2130	2280	2720	2880	3040
30	830	920	1010	1110	1210	1320	1430	2210	2350	2820	2980	3150
32	860	950	1050	1150	1260	1370	1480	2280	2430	2910	3080	3250
34	880	980	1080	1180	1290	1410	1530	2350	2510	3000	3170	3350
36	910	1010	1110	1220	1330	1450	1580	2420	2580	3080	3260	3440
38	930	1040	1140	1250	1370	1490	1620	2480	2650	3170	3350	3540
40	960	1060	1170	1290	1400	1530	1660	2550	2720	3250	3440	3630

* Computed with coefficient, c=0.90, to nearest 10 gallons per minute.

MEASURING DISCHARGE FROM NOZZLES



The discharge from any nozzle is given by the formula

$$Q \text{ - in USgpm} = 29.83\, d^2\, c \sqrt{Pv} = K \sqrt{Pv}$$

Where Pv = pitot gauge reading i psi.
d = diameter of nozzle tip in inches.
C = a coefficient less than 1.00 since in practice 100% efficiency cannot be achieved.
K = discharge constant for a particular nozzle

Some typical Coefficients of Discharge "C"

Sprinkler	.75
Hydrant Butt, smooth well rounded outlet	.80
Hydrant Butt, outlet not smooth and well rounded	.70
Smooth tapered play pipes	.97
Deluge nozzles	.99
Open pipes smooth and well rounded	.90
Open pipes burred opening	.80

Typical Discharge Constants "K"

Sprinkler ½"	5.3 to 5.8
Sprinkler 17/32nd"	7.8 to 8.4
Play pipe 1-3/4"	88
Open tube 2½"	167

NOTE:

1. Measure the diameter of the nozzle tip, select the correct "C" for the nozzle type and apply.

$$Q = 29.83\ d^2C \sqrt{Pv}$$

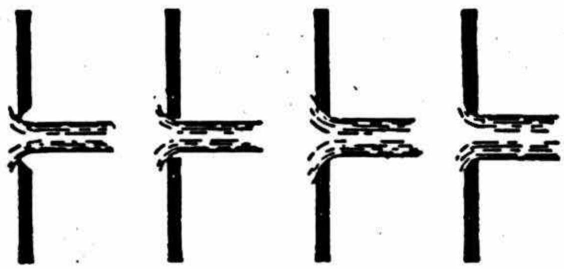
2. If you have a nozzle with K stamped on it, use

$$Q = K \sqrt{Pv}$$

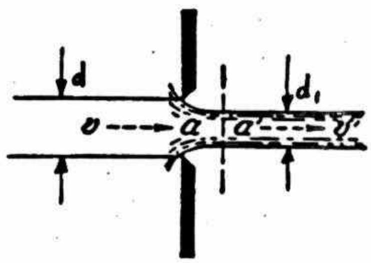
3. If you have tables available, read directly using the correct tip size and "C" valve. When using hydrant butts, use a table for 2½" outlets with a C of .90 already built in and apply the correction factor shown on the attached diagram.

4. A smooth nozzle should have a length at least six times the diameter in order to guarantee as smooth a flow as possible. This is more important in straight tubes than in tapered nozzles.

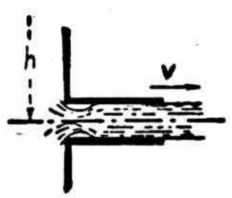
The effect of nozzle design on the Coefficient of discharge



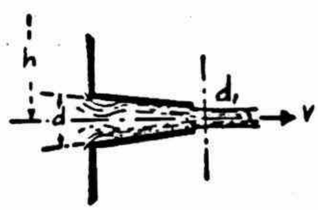
$C \doteq .7$ $C \doteq .8$ $C \doteq .90 - .99$ $C \doteq .95 - .99$



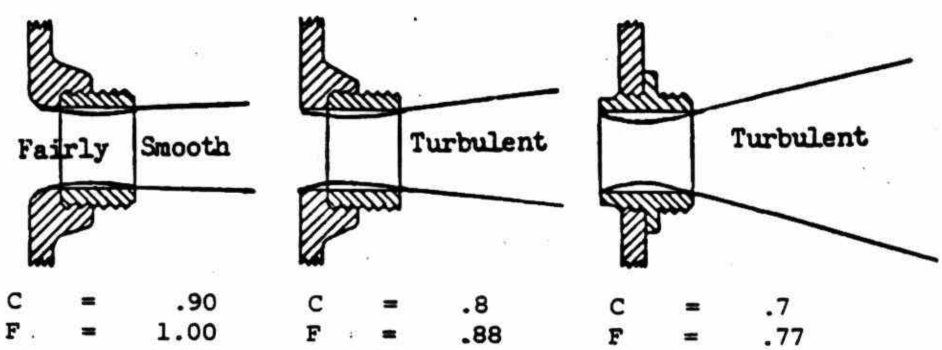
Stream dia. less than orifice diameter.



C = .90



C = .99



C =	.90	C =	.8	C =	.7
F =	1.00	F =	.88	F =	.77

Note: F is the multiplying factor for use with tables for the discharge for circular outlets with a built in C. of 0.90.

SUBJECT:	TOPIC: 12
DISTRIBUTION SYSTEM MAINTENANCE	Water main Breaks

OBJECTIVES:

The trainee will be able to:-

1. Recall the procedures required to deal with watermain breaks.

2. Based on visual aspects of a break, identify the possible reason for a failure.

3. Recall considerations which when installing a water line will assist in keeping breaks to a minimum.

WATERMAIN BREAKS AND REPAIRS

General

A broken main is an unplanned event and for this reason trained personnel, records, maps, repair parts, etc. must be available.

In any system a serviceman should be on duty for 16 hours out of 24 hours with a back-up serviceman and foreman available, throughout the 24 hour period, for seven days, working his normal day shift with a second serviceman to provide assistance from 5:00 p.m. to 8:00 a.m. This serviceman would be first called after the hours of 1:00 a.m. to 8:00 a.m. the following morning. A central control or operating centre manned 24 hours a day each day of the week is necessary where all calls can be received and acted upon.

When a main breaks the first consideration should be to get the water under control, by a complete or partial shut-down. The valves operated and their operating condition should be recorded. The section of the system that is out of service is reported; the location of all hydrants affected are reported to the Fire Department. The affected consumers including buildings with sprinkler systems, water-cooled refrigeration units, etc., are notified. If these buildings are unoccupied notify the owner, manager or agent.

Equipment required

The equipment requirements could include:

1. The Waterworks Trouble Truck equipped with:

   a. an up-to-date valve book;
   b. dip needle;
   c. complete set of keys to fit all valves;

d. pick axe;
e. sledge hammer;
f. propane burner to thaw frozen valve chambers;
g. manhole cover lifter;
h. two short-handled pointed shovels;
i. flashlight;
j. barricade and lights;
k. set of geophones;
l. two hydrant keys;
m. 100 feet of linen tape.

2. Safety equipment barricades, flashers, cones, men working signs.

3. Pipe cutters and saw.

4. Materials; clamps, couplings, mechanical joint sleeves, pipe.

5. Generator and lights for night use.

6. Compressor and gun.

7. Tractor back-hoe and loader.

Locating the Break

The area should be surveyed for any visible damage or flooding that has taken place. Snow and ice will be melted or earth deposited along the course the escaping water has followed. The following could be found at a main break: -

1. Under-mining of roads, walks, railways, other utilities, etc.

2. Flooded basement.

3. Plugged or restricted sewers.

4. Slippery driving conditions caused by flooding of freezing water. It may be necessary to arrange for Police assistance for the directing of traffic. Salt and sanding operations may be necessary.

Using one of the leak detection methods, if necessary, the point of the break is defined. Another method that is used to determine the point of break is the use of a heavy duty post-hole auger equipped with a frost cutter; by putting down a series of test-holes the void under the frozen earth will soon be located.

Excavation

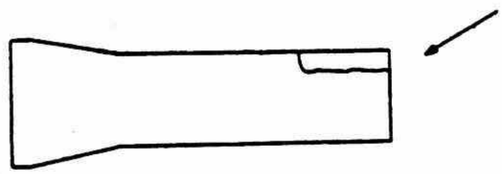
Before starting to excavate other utilities should be contacted - i.e. Bell Telephone Company, Gas Company, Hydro Company and Sewer Sections. A clearance should be obtained from those utilities to ensure that there is no underground plant buried within the excavation area that is proposed. Failing to obtain a proper locate or a locate of any kind could result in further damage to another utility's system.

Other topics deal with the considerations related to excavation, bedding, installation and site restoration. Once the repairs are made, the section must be cleaned, disinfected and pressure tested before being restored to service.

Diagnosing the Main Break

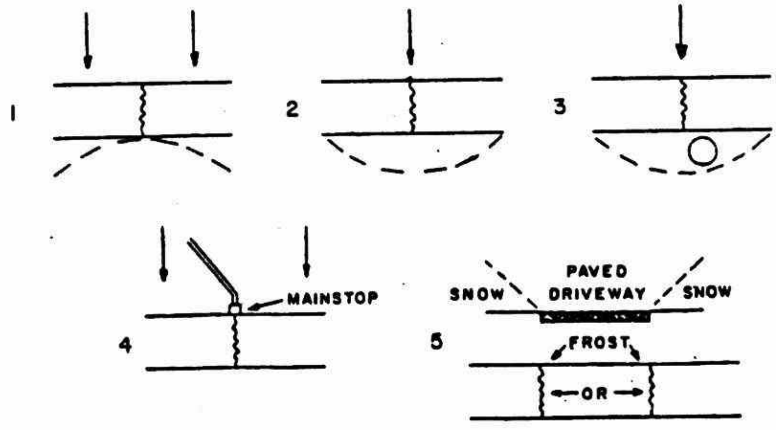
It is useful to consider the various visual aspects of a main break. These themselves help to diagnose the reason for a failure.

1. Impact



The longitudinal tear usually occurs under test pressure, the direct result of impact to the spigot end, before or during installation. This may occur due to improper unloading of trucks; i.e. throwing pipes off the truck, rather than unloading with mechanical or controlled means. Impact can also occur when pipes are thrown into the trench hitting a previously installed pipe. Rocks falling in off the sides, or when backfilling, can also cause impact.

2. Frost Penetration



Frost, by itself, does not break pipes. However, as shown in Figures (1) and (2) improper bedding assists frost in creating circumferential failures.

A sewer pipe installed laterally without proper support to the water main (as seen in Figure 3) promotes a failure similar to Figures (1) and (2).

A circumferential break at the main stop (see Figure 4) is caused by the service pipe being held rigid by the frozen ground while the frost penetration creates excessive stress on the rest of the pipe.

Many breaks are due to the streets and driveways being kept clear of snow. The snow piled high off to the side of the pavement, acts as a ground insulator, preventing frost penetration, while the clean pavements encourage a greater depth of frost. See Figure 5.

3. Main Contraction

Systems that are supplied with a surface source of water are susceptible to a wider range of temperature changes than well supplies. Contractions and expansions in the rigidly jointed water mains can cause circumferential breaks. The modern rubber gasketed flexible joint should offset this problem.

4. Hammer and Air Lock

Pressure testing a water line without releasing all the air at the high spots can burst a pipe. Quick closure of a valve, creating water hammer, can give the same result. This can be evidenced when a whole section of the pipe has come away.

MINIMIZING BREAKS

In order to keep breaks to a minimum, the following should be given careful consideration when designing and installing a water line:

a. select the proper class of pipe for the job;
b. reliable staff should be on the site at all times to supervise the off loading and installation;
c. ensure that the main is installed to minimum standards of "no blocking, flat bottom trench, and tamped backfill";
d. do not permit the undermining of the water line by other utilities without adequate support;
e. make certain that air relief valves are installed; especially if main is located in hilly area;
f. do not permit operation of valves or hydrants by unauthorized personnel;
g. do not tap services into the top of the main. Recommended locations are at "10 O'Clock" and "2 O'Clock";
h. evaluate every break by filling a "Water Main Failure Report". See Appendix A.

______________________________ NO. __________

____

WATER MAIN FAILURE REPORT

FIELD DATA FOR MAIN BREAK EVALUATION

DATE OF BREAK ______________________ TIME: ________ A.M. ________ P.M.

TYPE OF MAIN: ____________ SIZE ________ JOINT ____________ COVER _____ FT. _____ IN.

THICKNESS AT POINT OF FAILURE ____________ INCH.

NATURE OF BREAK: Circumferential ☐ Longitudinal ☐ Circumferential & Longitudinal ☐ Blowout ☐ Joint ☐

Split at Corporation ☐ Sleeve ☐ Miscellaneous ______________________ (describe) ☐

APPARENT CAUSE OF BREAK: Water Hammer (surge) ☐ Defective Pipe ☐ Corrosion ☐ Deterioration ☐

Improper Bedding ☐ Excessive Operating Pressure ☐ Differential Settlement ☐ Temp. Change ☐ Contractor ☐ Misc. ____________ (describe) ☐

STREET SURFACE: Paved ☐ Unpaved ☐ TRAFFIC: Heavy ☐ Medium ☐ Light ☐

TYPE OF STREET SURFACE ______________________ SIDE OF STREET: Sunny ☐ Shady ☐

TYPE OF SOIL ______________________ RESISTIVITY ________ ohm/cm

ELECTROLYSIS INDICATED: Yes ☐ No ☐ CORROSION: Outside ☐ Inside ☐

CONDITIONS FOUND: Rocks ☐ Voids ☐ PROXIMITY TO OTHER UTILITIES ______________

DEPTH OF FROST ______ INCH DEPTH OF SNOW ______ INCH

OFFICE DATA FOR MAIN BREAK EVALUATION

WEATHER CONDITIONS: PREVIOUS TWO WEEKS ______________________

SUDDEN CHANGE IN AIR TEMP ? Yes ☐ No ☐ TEMP. ________ °F. RISE ________ °F. FALL ________ °F.

WATER TEMP.: SUDDEN CHANGE: Yes ☐ No ☐ TEMP. ________ °F. RISE ________ °F. FALL ________ °F.

SPEC. OF MAIN ______________ CLASS OR THICKNESS ________ LAYING LENGTH ______ FT.

DATE LAID ____________ OPERATING PRESSURE ________ PSI. PREVIOUS BREAK REPORTED ____________

INITIAL INSTALLATION DATA:

TRENCH PREPARATION: Native Material ______________ (describe type) ☐ Sand Bedding ☐ Gravel Bedding ☐

BACKFILL: Native Material ☐ DESCRIBE ______________ Bank Run Sand & Gravel ☐

Gravel ☐ Sand ☐ Crushed Rock ☐ OTHER ______________

SETTLEMENT: Natural ☐ Water ☐ Compactors ☐ Vibrators ☐ OTHER ______________ (describe)

ADDITIONAL DATA FOR LOCAL UTILITY USE

LOCATION OF BREAK ______________________ MAP NO. ________

REPORTED BY ______________________

DAMAGE TO PAVING AND/OR PRIVATE PROPERTY ______________________

____

REPAIRS MADE (Materials, Labor, Equipment) ______________________

____

REPAIR DIFFICULTIES (If Any) ______________________

____

INSTALLING CONTRACTOR ______________________

SUBJECT:

DISTRIBUTION SYSTEM MAINTENANCE

TOPIC: 13

Cleaning Disinfection Testing

OBJECTIVES:

The trainee will be able to:-

1. Recall the reasons for cleaning disinfecting and testing watermains
2. Recall the limitations of flushing watermains
3. List the two methods of watermain chlorination
4. State the three methods of application for chlorine
5. Recall the purpose of flushing after chlorination
6. Calculate the amount of disinfectant required to disinfect a main
7. Clean and disinfect a watermain
8. Carry out pressure and leak test a watermain.

CLEANING DISINFECTION TESTING

GENERAL

When a new watermain is laid or an existing watermain has been repaired, it must be thoroughly cleaned, disinfected and tested for water tightness. This practice is necessary to:

1. Protect the consumers from infection. In all likelihood, the newly constructed system will have sustained contamination during the transit and storage on the site of the components and laying of the piping. Often the pipe must be laid in soggy trenches and possibly on occasions be in contact with wastewater or even sewage admitted into the trench through service cuts.

2. prevent the growth of nuisance organisms in the distribution system creating bad taste, odours and discoloured water.

3. Prevent contamination by a dirty new watermain of the existing water distribution system.

4. Remove any dirt and debris in the piping which, if left in the main, will shield bacteria and result in incomplete disinfection.

5. Confirm that the quality of workmanship and materials used in the job meets the required standards.

6. Alleviate customer complaints

CLEANING

Cleaning of watermains can be successfully accomplished by foam swabbing and/or flushing. This removes encrustations, debris, rust, and other foreign objects from a distribution system. It may also be used to restore the carrying capacity of the water mains.

When a consumer complaint is received, regarding discoloured water or taste or odour in a particular area of the distribution system, one is faced with the problem of rectifying the situation. What caused the problem? Was it due to the use of a fire hydrant for flushing or for fighting a fire? Could it be caused by an unusually high flow in that area of the system? If the customer has had the problem reoccur, the situation becomes even more undesirable.

In any event, the normal procedure is to dispatch a work crew and flush the main through a hydrant or other blow-off. However, unless exceptionally high flows can be maintained, the amount of debris removed will be minor. The table below indicates minimum flows, for various sized mains which will be effective for main flushing.

Pipe Diameter	Minimum Effective Flow for Hydrant
3 inch	95 G.P.M.
4 inch	200 G.P.M.
6 inch.	540 G.P.M.

One must also consider the effect of flushing on the rest of the distribution grid. Very often, the problems in other areas are compounded by redistributing the debris in the mains.

When a main is flushed, a large amount of rust is removed in the first few minutes. The water then clears up rapidly and the job appears done. The flushing is stopped. However, within another month or so the problem recurs. Many man hours are used up in this procedure but, unless a planned program of flushing and swabbing is maintained, the benefits are doubtful.

FOAM SWABBING

Basically, this cleaning technique involves the insertion of a cylindrical polyurethane foam swab, manufactured slightly oversized for a specific pipe diameter, into an isolated section of the watermain at a convenient location, usually a fire hydrant. A pressurized supply of water is provided which forces the swab through the hydrant and along the watermain to an open hydrant downstream. Debris and the swab are ejected from the downstream hydrant. The technique is described in Appendix A.

Swabs are made of polyurethane foam which has compressibility, tensile strength, and the required density. Two grades are generally used; soft and hard. The swabs are cut into cylinders and the length is at least one and a half times the diameter. This latter sizing is to prevent the foam swab from tumbling over as it enters the main, thereby ensuring that it passes through the main as a cylinder. The following table lists suggested sizes for foam swabs.

Pipe Diameter	Swab Diameter	Swab Length
1½ inches	2 inches	4 inches
2 inches	2½ inches	5 inches
4 inches	5 inches	10 inches
6 inches	8 inches	12 inches
8 inches	10 inches	15 inches
10 inches	13 inches	19 inches
12 inches	15 inches	22 inches

It should be noted that for the first runs, the soft swab is generally used because it will tear easily and will not be easily held by any obstruction.

In order to effectively clean the main, velocities in the range of 4 feet per second should be used. Velocities in excess of this cause the swab to "slip" by material in the main, resulting in an inadequate job. The mains must be full of water, when swabbing, and a net or bag should be used to collect debris and particles of swab from the main. Before starting the procedure, WARN customers. Public relations could be strained severely if the customers happen to use water from the main just prior to or after the swab has passed their service.

For mains larger than 6 inches in diameter, it will be necessary to use excavation and pipe cutting in order to facilitate the entry of the swab into the main. It may be possible to place the swab into larger mains by removing the works of an "in-line" valve and using this as a point of entry. Mains in excess of 24 inches in diameter have been flushed by the foam swab method.

A flow test should be conducted on the main before the swabbing commences. After swabbing has been carried out another test should be made to determine if further swabbing is necessary.

DISINFECTION OF WATERMAINS

General

In a public water-distribution system, all newly laid watermains, or existing watermains which have been repaired, should be disinfected before placed into service. It is necessary to follow this practice in order to protect the consumers against the possibility of infection which could result from ingestion of water contaminated by disease producing organisms.

In general, the disinfection procedure following cleaning consists of:-

1. Chlorination
2. Final Flushing
3. Bacteriological Testing

CHLORINATION

At the present time chlorine is the only disinfecting agent in use for disinfection of watermains. Although there are other agents which would be satisfactory for disinfection purposes, their use has not as yet been generally accepted. Chlorine may be introduced into watermains.

1. As a gas using Gas Chlorination equipment (not so commonly used)

2. In solution, using Hypochlorination equipment

Gas Chlorination

A gas-water mixture is fed into the line with a solution feed-chlorinator. Dry gas may be fed directly into the main using proper equipment to regulate the rate of gas flow and provide effective diffusion of gas into the water which is simultaneously entering the pipe.

It is very important that, in both cases, the feeding arrangement must provide for preventing backflow of water into the chlorine cylinder.

HYPOCHLORINATION

A solution of water and chlorine-bearing compounds is most commonly used for disinfection of watermains, because of the relative ease and safety with which these solutions could be handled and applied. Three of the most common chlorine-bearing compounds which are readily available as commercial products and having a known chlorine content are:

1. Calcium Hypochlroite (Trade names - "HTH", Perchloron" and "Pittchlor") contains up to 70% available chlorine.
2. Chlorinated Lime or "bleaching power" contains approximately 33% available chlorine.
3. Sodium Hypochlorite a variety of liquid solutions containing between 5% and 14% available chlorine.

These compounds are normally fed as a water mixture to yield one per cent of available chlorine in solution.

APPLICATION

Continuous Feed

The chlorine, fed either by a gas feeder or a hypo feeder, is introduced into the watermain through a corporation stop at the top of the pipe at the start-point of the new line. Simultaneously, water from the existing distribution system or other suitable (approved) source is introduced into the pipeline undergoing disinfection. The flow of water and chlorine mixture should be fairly accurately proportioned so the chlorine dosage will be no less than 50 mg per litre. Subsequent to filling the pipeline,

the chlorinated water should remain in it for at least 24 hours. During this time all new valves and other appurtenances within the system should be operated to expose all components to disinfection. A chlorine residual test should be done at a number of selected locations to ensure that the strength of chlorine is 25 mg per litre in the system at the end of the 24 hours period. If the residual chlorine is not at least 25 mg per litre, the contact period of 24 hours with a new starting solution of 50 mg per litre must be repeated.

Under certain conditions it may not be feasible to retain the chlorinated water in the pipeline for 24 hours. In such cases, by increasing the chlorine concentration, the retention time may be decreased. This practice, however, should be carried out with consultation and agreement of the local health authority or other agency responsible for proper disinfection of the system. High concentrations of chlorine, 100 mg/litre or higher, should be used only in emergencies because of the possibility of damage by highly corrosive chlorine to the pipe, valves, hydrants and other appurtenances.

Slug Method

This method is suitable for use with mains of large diameter for which, because of the volumes of water involved, the continuous feed method is not practical.

Water from the existing distribution system or other approved source of supply is made to flow at a constant, measured rate into the newly laid pipeline. The water receives a dose of chlorine, also fed at a constant, measured rate. The two rates are proportioned so that the concentration in the water entering the pipeline is maintained at no less than 300 mg/litre. The chlorine is applied continuously and for a sufficient period to develop a solid column or "slug" of chlorinated water that will, as it passes along the line, expose all interior surfaces to a

concentration of at least 300 mg/ litre for at least 3 hours. The application is checked at a tap near the up-stream-end of the line by chlorine residual measurements.

As the chlorinated water flows past tees and crosses, related valves and hydrants are operated so as to disinfect appurtenances.

Tablet Method

In this practice, calcium hypochlorite tablets are placed at predeterminated spacing in the pipeline during construction. The line is then filled with clean water very slowly at a velocity of less than one foot per second to prevent the tablets from washing to the end of the main, but instead to dissolve in place. Because this method requires the placing of the chlorine tablets during construction, thus exposing the compound to moisture in the trench or flooding, and because it precludes preliminary flushing of the pipeline it is the least satisfactory. Its practice should be avoided.

FLUSHING

Following the prescribed retention period, the chlorinated water should be evacuated from the mains by proper flushing and filling of the system with clean potable water that has been proven, through bacteriological testing, to be free of contamination.

No highly chlorinated water must be allowed to pass into the existing system. The Local Authority should be advised when this work is to be done. If the highly chlorinated water cannot be diluted before discharge to a sewer system or a watercourse, it should be drained off into a holding pond or tank. The chlorine will then settle to the bottom and the holding unit drained from the surface down. The small amount of heavily chlorinated water remaining at the bottom can then be disposed of by a suitable sanitary method.

Calculations for Pipeline Chlorination

Three of the more common materials used to provide chlorine for watermain disinfection are: HTH, Sodium Hypochlorite solution and Javex solution.

The latter two may be used when it is difficult to dissolve sufficient quantities of HTH.

The normal strength of watermain disinfection is 50 mg/L for 24 hours leaving a residual of 25 mg/L. The amount of chlorine required may be calculated from the following:

1. Size of the pipe,
2. Length of the pipe,
3. Percentage of available chlorine in the material,
4. Dosage desired.

For quick calculation of material requirements to give the required chlorination, use the following formulae:

Objective: to dose at 50 mg/L chlorine

Data: diameter of pipe in inches, d
length of pipe in feet, L

Equation 1 Using HTH 70% effective chlorine (pellets or powder)

$$\text{lb HTH required} = \frac{d^2L}{41{,}135}$$

Equation 2 Using Javex solution at 6% available chlorine

$$\text{Gallons Javex required} = \frac{d^2L}{35{,}259}$$

Equation 3 Using sodium hypochlorite solution at 12% strength

$$\text{Gallons hypochlorite required} = \frac{d^2L}{70{,}518}$$

To correct for chlorine dosages different from 50 mg/L multiply above equations by (.02 x required dosage in mg/L).

To correct for Javex concentrations different from 6% multiply Equation 2 by $\frac{6}{\text{Actual \% Chlorine}}$

To correct for sodium hypochlorite concentrations different from 12% multiply Equation 3 by $\frac{6}{\text{Actual \% Chlorine}}$

The following calculations show how the three equations are derived:

1 $\frac{d^2L}{41,135}$

Volume of the pipeline = area x length

$$= \frac{\pi \times d^2}{4} \times L$$

Where d is in inches and L is in feet.

$$\text{Volume} = \frac{\pi \times d^2 \times L}{4 \times 144} \ ft^3$$

$$= \frac{\pi \times d^2 \times L \times 6.24}{4 \times 144} \text{ gallons}$$

To obtain a dosage of 50 mg/L

Needs 50 gallons per 1,000,000 gallons but a gallon water weighs 10 lbs we need 50 x 10 = 500 lbs. of chlorine per 1,000,000 gallons or 50 lbs per 100,000 gallons.

$$\text{Dosage} = \text{Volume (gallons} \times \frac{\text{mg/L desired}}{100,000 \times \text{\% chlorine available}}$$

HTH has 70% available chlorine

$$\text{or Dosage} = \frac{\pi \times d^2 \times L \times 6.24 \times 50 \text{ mg/L}}{4 \times 144 \times 100,000 \times 0.7} = \frac{d^2L}{41,135}$$

2 $\frac{d^2L}{35,259}$

$$\text{Volume of the pipeline} = \frac{\pi \times d^2 \times L \times 6.24}{4 \times 144} \text{ gallons}$$

Since Javex comes in liquid form, we need 50 gallons per 1,000,000 gallons

$$\text{Dosage} = \text{Volume (gallons)} \times \frac{\text{mg/L desired}}{1{,}000{,}000 \times \%\ \text{chlorine available}}$$

Javex has 6% available chlorine

$$\text{Dosage} = \frac{\times\ d^2 \times L \times 6.24 \times 50\ \text{mg/L}}{4 \times 144 \times 1{,}000{,}000 \times 0.06}$$

$$= \frac{d^2L}{35{,}259}$$

3 $\frac{d^2L}{70{,}518}$

Since Sodium Hypochlorite has 12% available chlorine

$$\text{Dosage} = \frac{\pi \times d^2 \times L \times 6.24 \times 50}{4 \times 144 \times 1{,}000{,}000 \times 0.12}$$

$$= \frac{d^2L}{70{,}518}$$

Examples

Assume a 12 inch main, 1000 feet long, strength required = 50 mg/L

1 HTH $\frac{d^2L}{41{,}135} = \frac{12^2 \times 1000}{41{,}135} = 3.5$ lbs

2 Javex $\frac{d^2L}{35{,}259} = \frac{12^2 \times 1000}{35{,}259} = 4.08$ gallons

3 Sodium Hypochlorite $\frac{d^2L}{70{,}518} = \frac{12^2 \times 1000}{70.518} = 2.04$ gallons

To correct for chlorine dosages different from 50 mg/L, multiply equations (1), (2) and (3) by (0.02 x new required dosage in mg/L).

i.e. New dosage = 25 mg/L

1 HTH $\frac{d^2L}{41,135} \times 0.02 \times 25 = 1.75$ lbs.

2 Javex $\frac{d^2L}{35,259} \times 0.02 \times 25 = 2.04$ gallons

3 Sodium Hypochlorite $\frac{d^2L}{70,518} \times 0.02 \times 25 = 1.02$ gallons

To correct for liquid chlorine concentration different from 6% or 12%.

Multiply equation (2) by $\frac{6}{\text{Actual \% } Cl_2}$

and Multiply equation (3) by $\frac{12}{\text{Actual \% } Cl_2}$

i.e. Use a chlorine solution with 30% available chlorine.

2 $\frac{d^2L}{35,259} \times \frac{6}{30} = 0.8$ gallons

3 $\frac{d^2L}{70,518} \times \frac{6}{30} = 0.4$ gallons

BACTERIOLOGICAL TESTING

After the new works have been adequately chlorinated and filled with clean fresh water, a prescribed number of water samples should be collected at predetermined locations and submitted to a laboratory for bacteriological examination. When the laboratory report has confirmed the water in the new system to be bacteriologically satisfactory, it may then be placed into service to the consumers, but never before. Should the laboratory results prove the water to be bacteriologically unsatisfactory, the disinfection of the system must be repeated.

When collecting samples, care should be exercised to make certain the sample is not contaminated by use of unsanitary techniques. Both the chlorination of the new works and the collection and submission of samples should be carried out by competent and reliable individuals. If these processes are left to careless procedures and techniques, chlorination of new watermains or the system appurtenances may result in great loss of time on the project and cause frustration to owners, constructors and the consumers.

PRESSURE AND LEAK TESTING

When construction or repair is completed and the pipeline has been disinfected and flushed, it should be tested for water-tightness. This will give an indication of the quality of workmanship and materials used in the water-main and its fittings. Normally, the main is tested for both pressure and leakage.

The normal test pressure is 150 p.s.i. (1034 KPa), which is well above the maximum working pressure of a water system. The leakage standard used by the Ministry of the Environment is 20 Imp. gals/day per inch of internal diameter of pipe per mile of pipe (2.2 litres/day per mm of internal diameter of pipe per kilometre of pipe).

The method is as follows:

1. Make sure that all anchors and thrust blocking have been installed in the pipe.

2. Install a pressure pump with make-up reservoir in the system to be tested. It should be installed at the end of the pipe, at a service connection or at a hydrant.

3. Start filling the test section with water

4. Start applying partial pressure with the pump. Before bringing the pressure to the full test value, bleed all air out of the mains by venting through hydrants, service connections and air release valves.

5. Once the lines are full and all air has been

let off, leave on partial pressure and allow the pipe to soak at least 24 hours.

6. For pressure testing, subject the test line to hydrostatic pressure of 150 p.s.i. (1034 KPa) for a period of 30 minutes.

7. After the test pressure has been maintained for at least two (2) hours, conduct a leakage test by measuring with the make-up reservoir the amount of water that has to be pumped into the line in order to maintain the test pressured at 150 p.s.i. (1034 KPa) for one hour.

8. Measure the amount of leakage and compare it to the standard of 20 Imp. gals per day per inch of diameter per mile of pipe (2.2 litres/day per mm, dia. per kilometre of pipe).

9. If less than the allowable leakage has been measured, the line is satisfactory.

If the line has failed the leakage test, it is necessary to find the point or points where the excessive leakage is taking place. Before rushing off to dig up the entire line, there are a few steps that can be taken to ensure that it is a pipe leak, and not a leak at a fitting. First, leave the line under normal pressure. The next day, repeat the test. If the leakage measured the next day is greater than before, the leak probably is in a pipe joint or a damaged pipe. If the leakage is the same, it is more probably in a valve or a service connection.

To determine which it is, take the following steps. Insert the key for the curb stops in each shut-off, and listen at the top of the key. It may be possible to

hear a leak since the key acts somewhat like a stethoscope. If a leak is heard, open the shut-off and close it again. If there is now no audible leak, test the section again. If no leaking curb stops are found, crack the main valves at the ends of the test section several time and close them again. This is to flush out any sand grains in the valve seats that may prevent the valves from closing completely causing slight leakages.

If it is found that the leakage does not occur at either of the above points it is then necessary to try and find a leak through trail and error. Some sort of leak detector such as a sensitive microphone with amplifier and ear phones is necessary.

Any leaks in the line should be repaired, and the line re-tested until the measured leakage is less than the allowable leakage.

FOAM SWAB CLEANING TECHNIQUE

The procedure for a full scale operation would as follows:

1. Study an overall plan of the area to be cleaned and select suitable hydrants for entry and exit of the swab.

2. Make a sketch of the valve and watermain layout of the section to be cleaned and number all valves and hydrants.

3. Draft a detailed operating procedure, indicating which valves are to be opened or closed, which hydrants are to be used, and the estimated time of travel for each swab. A travel rate of 2.5 feet per second is used for estimating purposes.

4. Check all hydrants and valves in the area to be cleaned to ensure that they are operating satisfactorily.

5. Notify residents, businesses or industries along the watermain in question that the watermain will be cleaned and that water should not be used during the times indicated. Remember, if water is drawn into a service line at the time of cleaning, plugging could result or damage claims could be made because of the excessively dirty water.

6. Isolate the inlet and outlet hydrants and remove the internal mechanisms. Plug drain holes in the bottom of the hydrant, if possible, and insert the swab into the barrel of the entrance hydrant. Often, a launching device is constructed for this purpose.

7. After replacement of the bonnet for closing of the launching device, attach an external source of water, either a 2½ inch connection to another hydrant external to the isolated section, or a small high pressure pump with an independent water supply source.

   It should be noted here that this source of water is only required in order to get the swab down the hydrant and part of the hydrant branch to the main. When this occurs, the hydrant branch can be isolated, and the swab pushed along the main utilizing upstream water from the distribution system.

8. The swab is pushed along the watermain towards the exit hydrant at an approximate rate of 2-2½ feet per second. The passage of the swab should be timed during the initial runs in order to properly gauge the valve setting required for the upstream water supply.

The water flowing from the discharge hydrant will be clear in appearance when the pressure valve is opened. As the swab approaches the discharge opening the water will gradually become murky and then become quite discoloured. Just prior to the exiting of the swab the water will be a deep chocolate colour and particules will appear in the collecting bag.

After the swab exits from the hydrant discharge, the water flow should be increased to remove the dislodged material from the main. Depending on the condition of the main, the swab may be virtually intact or for all practical purposes completely useless due to extreme tearing.

Continue flushing until no further evidence of any dislodged material is apparent. As a further precaution, check the contents of the net to ensure that all parts of the foam swab are accounted for.

For illustration, a sample situation utilizing a fire pumper to inject the swab is shown at Figure 1. The detailed operating procedure is indicated below.

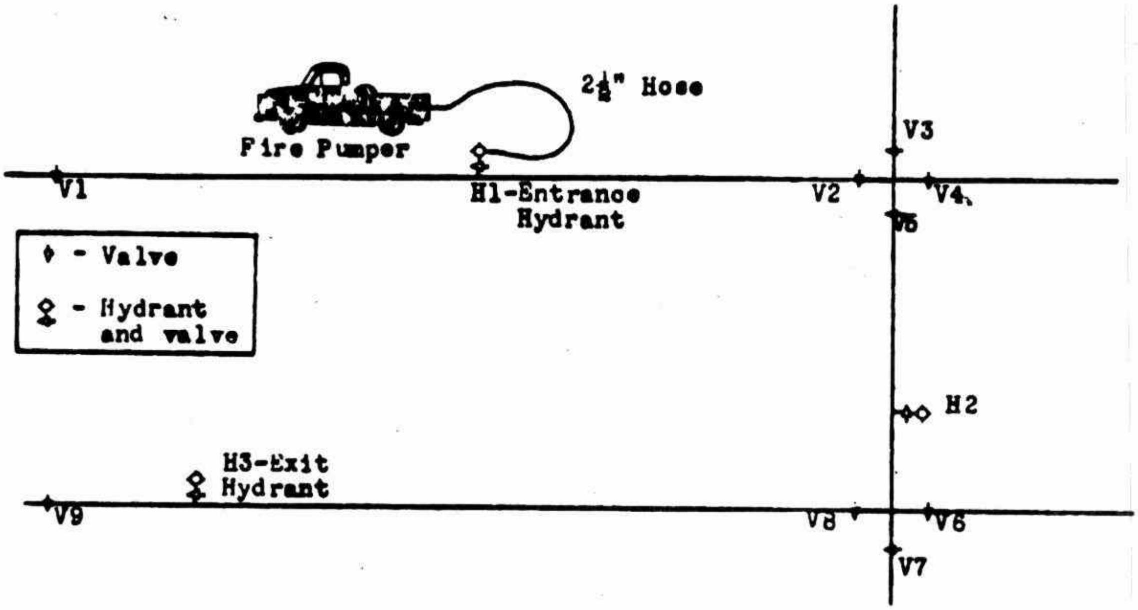


FIGURE 1 WORKING SKETCH OF LINE TO BE CLEANED

1. Before beginning swabbing operations:

<u>Valves</u>

Closed	Opened
V1	V2
V3	V5
V4	V8
V7	HV1
V9	HV3

2. Open H1 to ensure system is isolated, i.e. no flow.

3. Remove bonnet on H1 and H3. Remove internal mechanism if required.

4. Insert foam swab into barrel of H1.

5. Replace bonnet on H1.

6. Attach Fire Pumper to H1.

7. Pump swab into main.

8. Turn off fire pumper, close HV1, and crack open V1.

9. Check to ensure swab has left H1, open steamer cap and crack HV1 - if swab does not emerge, it is in the isolated section.

10. Time swab travel until emergence at H3.

11. Repeat above procedure for further passes.

12. On completion, open all valves closed for isolation purposes.

13. Re-assemble hydrants.

SUBJECT:

WATER DISTRIBUTION
SYSTEM OPERATIONS

TOPIC: 14

Cross Connections

OBJECTIVES:

The trainee will be able to:

1. define the term cross connection;
2. identify common cross connections;
3. recall the two (2) conditions which cause back-flow:
4. list five methods of preventing back-flow and the disadvantage(s) of each;
5. explain the operation of a reduced pressure backflow preventer.

CROSS CONNECTION AND CROSS CONNECTION CONTROL

INTRODUCTION

Cross connection of the potable water supply is not new. It has existed in one form or another since water mains were first installed and has been increasing annually at an alarming rate, particularly because of the industrialization of our province.

The seriousness of the problem continues to go unrecognized by authorities. Many municipalities even when aware of the hazards, actual or potential created by cross connection, do little or nothing to promote an effective CROSS CONNECTION CONTROL PROGRAM.

A cross connection is any connection to a potable water system which may be active, inactive or potentially hazardous, whereby water from any place or any solid or liquid or gaseous substance or any combination thereof may enter the potable water system. It occurs by backflow.

Provincial legislation and related standards provide the authority for enforcement by the municipal government. The municipal plumbing inspectors actively assisted and supported by the local water authority (e.g. P.U.C.) and the municipal health departments, can form a first line team to implement a program for the eradication of cross connection.

BACKFLOW

Backflow is a reversal of flow within a potable water system.

1. Syphonic Backflow caused by a drop in or negative mains pressure.

The water main is subject to fluctuation in pressure caused by:

a) high demand (exceeding capacity to supply);
b) use of hydrants during a fire (emergency demand);
c) broken water mains;
d) low reservoirs (dry seasons).

When this condition occurs, anything connected to the water system without adequate protection having been provided, can and may be literally sucked pack into the water main on the street. When pressure is restored any resultant contaminant could be delivered to any users premises.

2. Back Pressure Backflow caused through an unprotected connection to any equipment or device having a pressure higher than that available in the water main:

a) steam or hot water boiler;
b) pumps;
c) industrial or special equipment.

Again the contaminant, rust inhibitors, industrial chemicals, etc., can be distributed through the water to other users premises and/or to the domestic portion of the users own premises.

METHODS OF PREVENTING BACK FLOW

Air Gap

Air gaps in water distribution piping are considered by some people to be the only positive protection against back flow. That a proper air gap will protect a water system is true enough. It loses its reliability, however, because it is so easily bypassed and once this is done, it usually affords no protection at all.

It has another disadvantage in that it usually completely depressurizes the water often necessitating costly re-pumping.

Barometric Loop

A barometric loop is simply a vertical loop of pipe so high above the maximum water level on the downstream side that water cannot be forced back over the loop by atmospheric pressure.

Such an arrangement has the advantage that water need not be depressured and yet will not reverse by syphonic action.

It loses all protective value, however, if the downstream side is subject to pressures other than atmospheric.

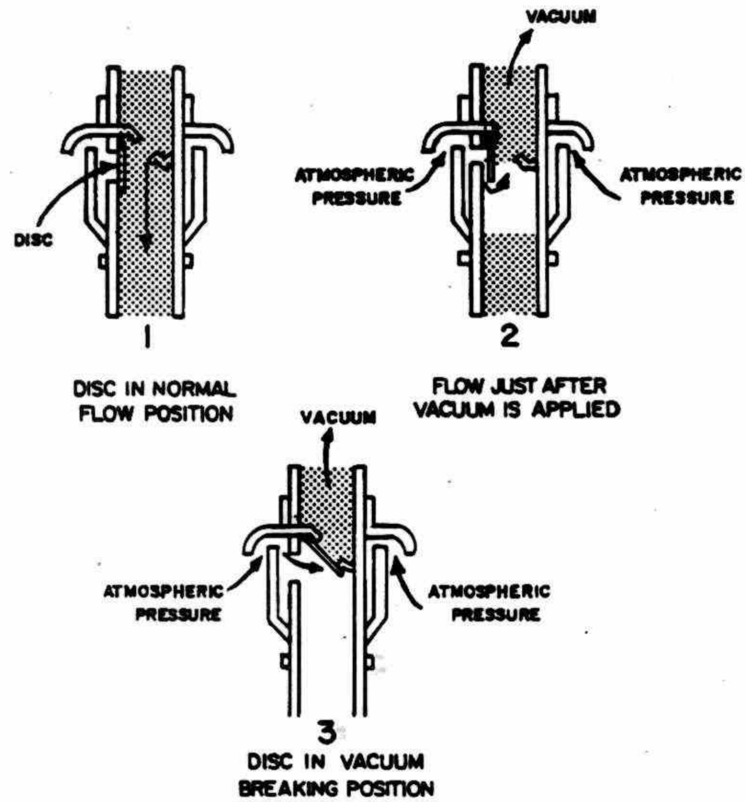
Vacuum Breaker

A vacuum breaker offers about the same degree of protection as a barometric loop. Its advantage is less room required and usually a lower cost price. It is, however, subject to mechanical failure in addition to its inherent limitations. See Figures 14.1 and 14.2.

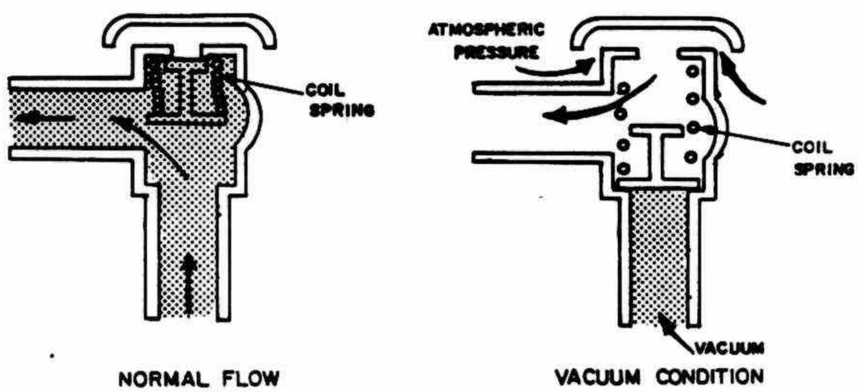
FIGURE 14.1

OPERATION OF A VACUUM BREAKER

(1) SWINGING DISC TYPE



(2) SLIDING SPOOL TYPE



NOTE: This shows the principle of operation. Other types have a sliding spool which closes the air inlet when there is forward flow.

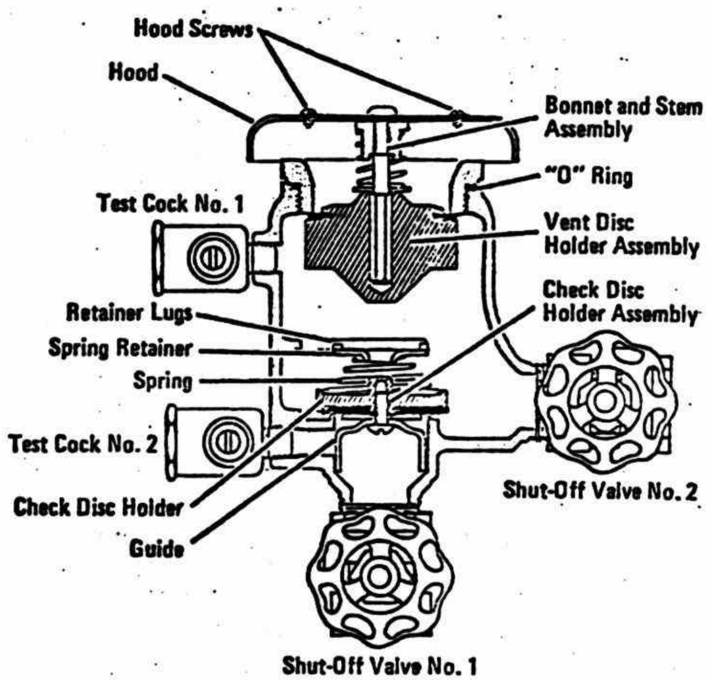


FIGURE 14-2 ANTI-SIPHON PRESSURE TYPE VACUUM BREAKER

Check Valves

Where the discharge openings of a water distribution system are submerged and the back pressures are apt to be above atmospheric, back flow cannot be prevented by barometric loops or vacuum breakers and a check valve arrangement of some kind is usually resorted to.

A single check valve when functioning as intended, will prevent back flow. Check valves are, however, subject to mechanical failure and for that reason a single check valve in a supply pipe is not considered adequate to reduce the hazard to an acceptable level.

If two check valves are installed in series there is still a chance that both may fail but the mathematical probability of both valves failing is less than the probability of one valve failing.

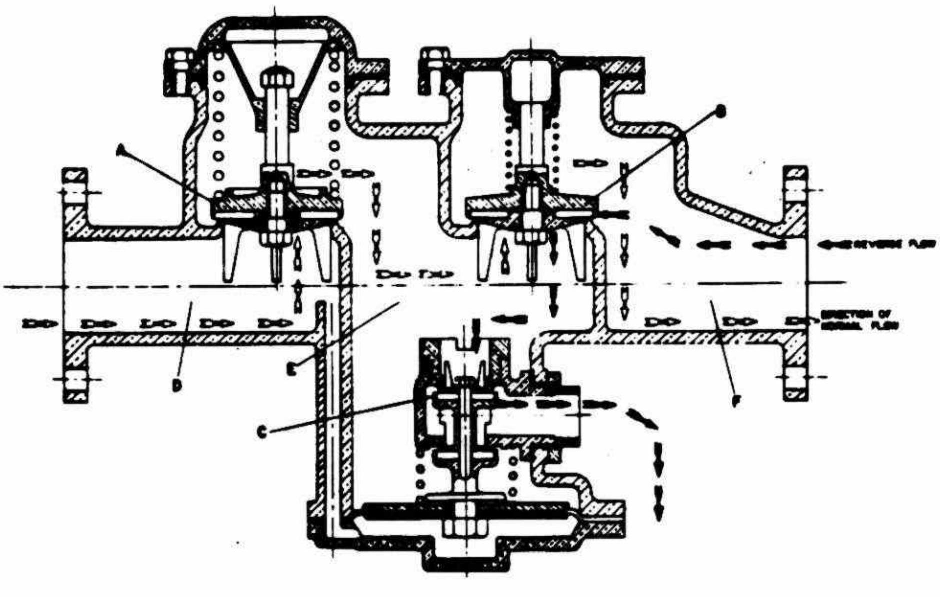
If we further add two gate valves, one before and one after the check valves so the gate valves may be used to isolate the check valves for service and maintenance, the degree of protection is further improved.

The next step is to install test cocks between valves so they may be tested to know when repairs or maintenance are required.

Reduced Pressure Zone Back Flow Preventor

The reduced pressure zone back flow preventor Figure 14.3 consists of the double check and double gate valve arrangement described above with further refinements incorporated. The reduced pressure zone is the volume enclosed between the two check valves. The reduced pressure is obtained by spring loading the first check valve (in direction of normal flow). In normal operation the water pressure in the reduced zone would always be less than the

Figure 14-3 REDUCED PRESSURE BACKFLOW PREVENTER



The Beeco Model 6-C Reduced Pressure Backflow Preventer contains the following operating parts:

2 Spring-Loaded Vertical Check Valves (A and B)
1 Spring-Loaded, diaphragm actuated, Differential Pressure Relief Valve (C)

Check Valve A is spring-loaded to a closed position, and causes all water passing through it to be automatically reduced in pressure by approximately 8 pounds per square inch.

Check Valve B, which forms the "double check" feature of the device, also acts to prevent unnecessary drainage of the domestic system in case a backflow condition occurs. This valve is lightly spring-loaded and, therefore, very little pressure reduction is made in passageway F and in the pipe lines beyond.

Relief Valve C is spring-loaded to remain open, and diaphragm actuated to close--by means of differential pressure.

To illustrate the operation, we will assume water, having a supply pressure of 60 psi, is flowing in a normal direction through the device (as shown by the white arrows). If we close all valves beyond Area F, creating a static condition, the water pressure in Area D will be 60 psi and the water pressure in Zone E will be 52 psi.

The inlet pressure of 60 psi is transmitted through a cored passageway to the underside of the diaphragm of Relief Valve C. This valve is spring-loaded to remain in an open position until the differential pressure amounts to 4 psi or more.

Therefore, during normal operation, the 8 psi differential pressure produced by Check Valve A exceeds the spring-loading of Relief Valve C and causes Valve C to remain closed.

pressure in the reduced zone would always be less than the supply pressure by the amount of the spring loading. Should there be a pressure drop in the supply or a pressure increase on the delivery side with accompanying leakage through the downstream check valve, the reduced pressure zone is kept below the supply pressure by bleeding to atmosphere.

The drain valve from the reduced pressure zone to atmosphere is controlled by a spring-loaded diaphragm. One side of the control diaphragm is subjected to supply pressure and the other to pressure in the reduced zone. The supply pressure tends to close the drain valve. The pressure in the reduced zone plus the spring pressure tend to open the drain valve.

In this way, assuming the worst possible situation, namely, all valves leaking, a back-up of water through the downstream check valve would be drained to atmosphere before the pressure in the reduced zone would build up high enough to force water back through the upstream check valve.

COMMON CROSS CONNECTIONS

1. Any water faucet with a hose connected which can reach a contaminating fluid.

2. A submerged discharge such as a flushometer water closet.

3. Direct connected trap seal primers.

4. Fire protection systems cross-connected with potable water systems (sprinkler system).

5. Fire hydrants cross-connected with polluted ground water.

6. Water operated devices such as ejectors, aspirators, sprayers, aerators.

SUBJECT:

DISTRIBUTION SYSTEM MAINTENANCE

TOPIC: 15

Corrosion

OBJECTIVES:

The trainee will be able to recall

1. Corrosion mechanism and accelerating factors

2. Methods of Corrosion Prevention and their application to
   a. Existing Piping Systems
   b. Extensions of existing system

3. The benefits of a corrosion protection program.

CORROSION AND CATHODIC PROTECTION OF UNDERGROUND METALLIC WATER PIPING SYSTEMS

INTRODUCTION

During 1977, one Borough in Metropolitan Toronto spent more than $800,000.00 for repair of 479 water main breaks. A second Borough experienced more than 700 failures (approximately 1 failure per mile) during the same period. A major Western Canadian City is approaching 1,000 failures per year. Unquestionably this is a serious situation particularly since the number of annual failures in all cases are increasing yearly.

These water distribution facilities comprise cast iron piping and ductile iron piping, in which most of the ductile iron piping was installed during the 1960's and later. Failures occurred on both the ductile and cast iron piping. Failures on cast iron piping were generally described as 'breaks' usually attributed to the lack of ductility. However, failures on ductile iron were generally 'leaks' as a result of perforation by corrosion. The corrosion failure of ductile iron after a comparatively short service life, however alarming to the municipalities, demonstrates that the primary cause of cast iron main breaks is corrosion.

CORROSION OF CAST IRON AND DUCTILE IRON PIPING

Several authors have stated that the major cause of breaks in cast iron piping is corrosion. It is understandable that this view is not more widely accepted because of the nature of cast iron corrosion. When the ferritic component of grey cast iron corrodes it leaves behind a flaked graphite matrix which usually retains the original

shape of the structure and its ability to withstand the operating pressure. This corrosion process called 'graphitization' camouflages the fact that corrosion has taken place and leads to the unfortunate conclusion that cast iron has good corrosion resistance. Studies into the comparative corrosion behaviour of malleable-iron carbon steel and cast iron have indicated that "there is no great difference in behaviour of these materials."

Had municipalities more closely examined cast iron main breaks by sand blasting the broken sections to remove the loose graphite matrix they no doubt would have found that substantial metal loss had occurred leading to weakening of the pipe and leaving the piping subject to breakage by minor mechanical disturbances.

This failure, to recognize corrosion as the primary cause of cast iron water main breaks, has been compounded by the transition of most municipalities to the use of thinner ductile iron.

Corrosion pit depth (P) is a function of time (T). Typical curves of pit depth vs time for cast iron and ductile iron are shown in Figure 15-1.

Accordingly, ductile iron having a thinner wall thickness must therefore corrode through to perforation more quickly. For example 12"Ø grey cast iron of Class 28 has a wall thickness of 0.750" whereas 12" Ø ductile iron of Class 1 has a wall thickness of 0.320". In view of this, it is not surprising that ductile iron piping is exhibiting premature corrosion failure.

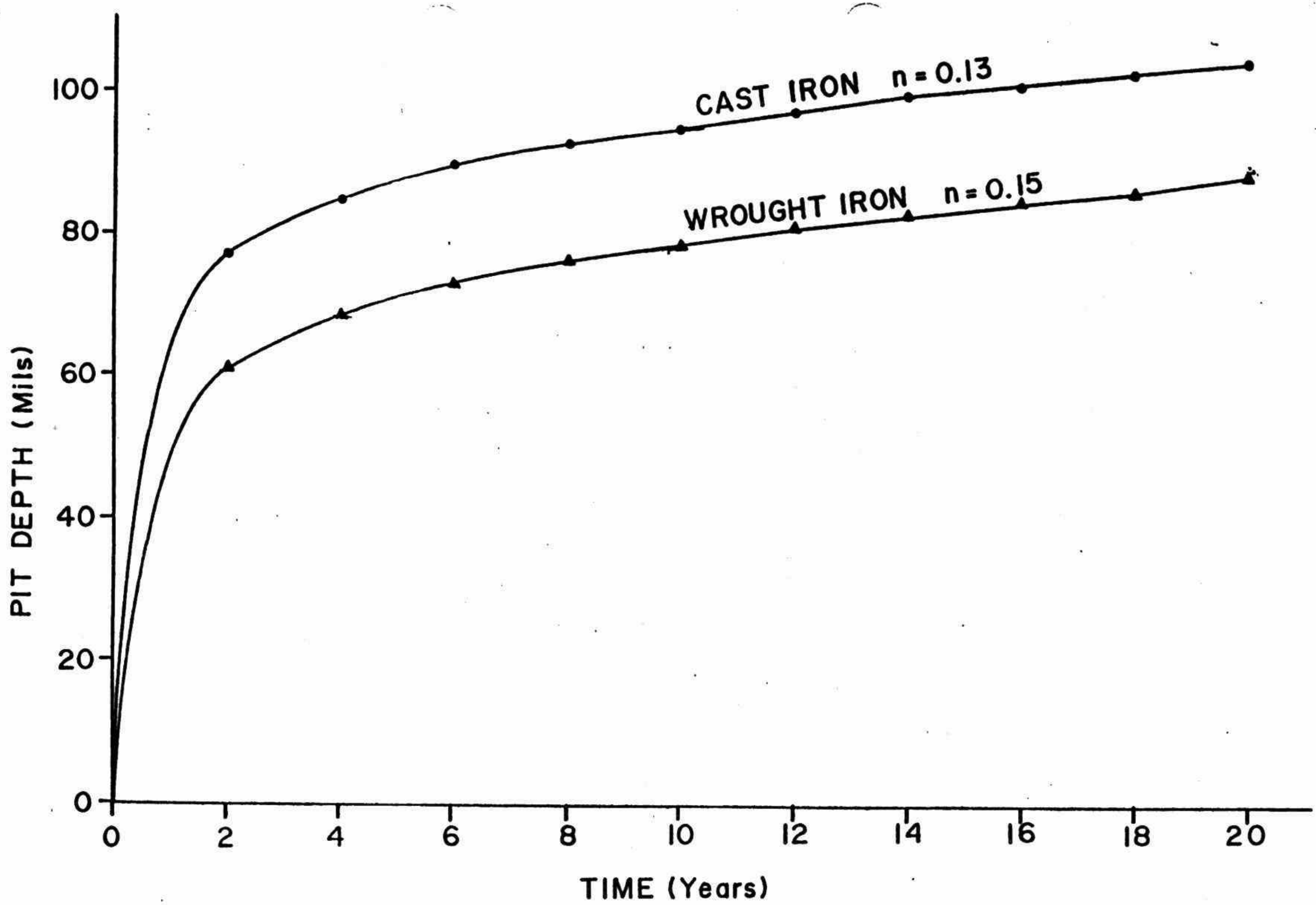


FIG. 15-1 - PIT DEPTH VS. TIME
SASQUEHANNA CLAY
(6,920 Ω cm.)

TABLE 15-1- GALVANIC SERIES

METAL	VOLTS
Magnesium (Commercially pure)	-1.75
Zinc	-1.1
Aluminum alloy (5% zinc)	-1.05
Commercially pure aluminum	-0.8
Mild steel (clean and shiny)	-0.5 to -0.8
Mild steel (rusted)	-0.2 to -0.5
Cast iron (not graphitized)	-0.5
Lead	-0.5
Mild steel in concrete	-0.2
Copper, brass, bronze	-0.2
High silicon cast iron	-0.2
Mill scale on steel	-0.2
Carbon, graphite, coke	+0.4

more active

more noble

CORROSION MECHANISMS

Corrosion is the deterioration of a substance (usually a metal) or its properties because of a reaction with its environment. The corrosion of a metal is often considered an unusual event, which is an erroneous presumption, since all metals are thermodynamically predestined to corrode.

During the reduction of an ore to its metallic state, energy is required to separate the metal from the non-metallic portion of the ore. The energy of separation places the metal in an energy rich state and the metal is said to have 'free' energy often called 'Gibb's free energy'. When the metal is placed in contact with an oxidizing agent such as oxygen, sulphur compounds, etc., the metal will oxidize, being driven to do so by its Gibb's free energy. Since extraction of metals from their respective ores involves different energies for each ore then it follows that each metal has a different 'free' energy and consequently a different propensity to corrode.

The tendency of metals to corrode can be measured electro-chemically to produce a list called the Electrochemical Series. The Electrochemical Series has been modified with respect to a sea water environment to produce the Galvanic Series, shown in Table 15-1. The series is tabulated by measuring the electrical potential of the metal with respect to a Cu:$CuSO_4$ electrode in sea water. The metals at the top of the Galvanic Series are the most active/or most likely to corrode and the metals at the bottom are the least active (more noble) or least likely to corrode.

Galvanic Corrosion Cells

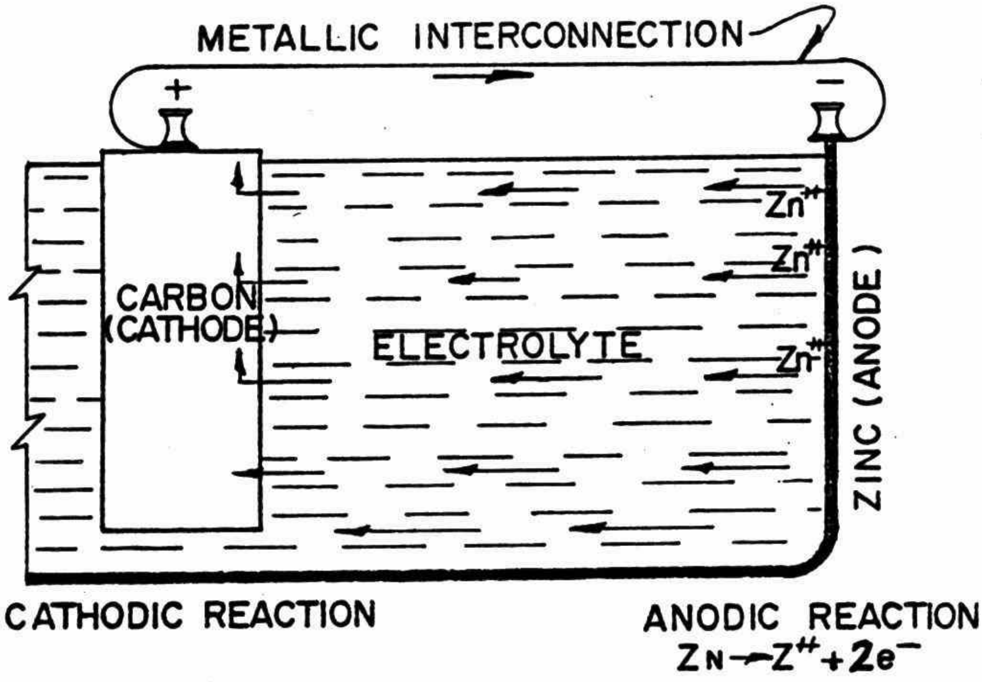
If different metals are interconnected in an electrolyte a galvanic cell is produced and a current flows.

between the interconnected metals. An example of a beneficial corrosion cell is the flashlight battery (Fig. 15-2). From the galvanic series we can see that if zinc and carbon are interconnected in the presence of an electrolyte, there is an electrical potential difference of approximately 1.5 volts. In this cell, the zinc is the most active metal and consequently corrodes, whereas the carbon post acts as a cathode. For a galvanic corrosion cell to exist, there must be an anode, a cathode, an electrolyte, and a metallic path between the two electrodes. Corrosion always occurs at the anode of a galvanic cell. Corrosion does not occur at the cathode.

A practical example of a detrimental corrosion cell which is particularly common to the waterworks industry is shown in Fig. 15-3. Here the iron main is interconnected to a copper service and the resulting galvanic cell consists of an iron anode, a copper cathode, a soil electrolyte and a direct metallic connection.

Another corrosion cell caused by dissimilar metals is shown in Fig. 15-4. From the galvanic series we can see that there is an electrical potential difference between new steel and old corroded steel. Accordingly, when a new piece of pipe is installed in an existing piping system, one can expect the new pipe (being the anode) to corrode whilst the old pipe participates as a cathode. This cell tends to explain why newly installed piping often corrodes to perforation before the exising piping.

Corrosion cells can also exist on the surface of the same metal. Differences in the nature of the soil in contact with a pipe can form corrosion cells, as in Fig. 15-5. The pipe buried in the lighter more porous loam soils is more likely to become the cathode whereas the metal in contact with the more impervious clay will become the anode. The above can also be considered a special case of a corrosion cell caused by differential aeration.



GALVANIC CORROSION CELL

FIGURE 15-2

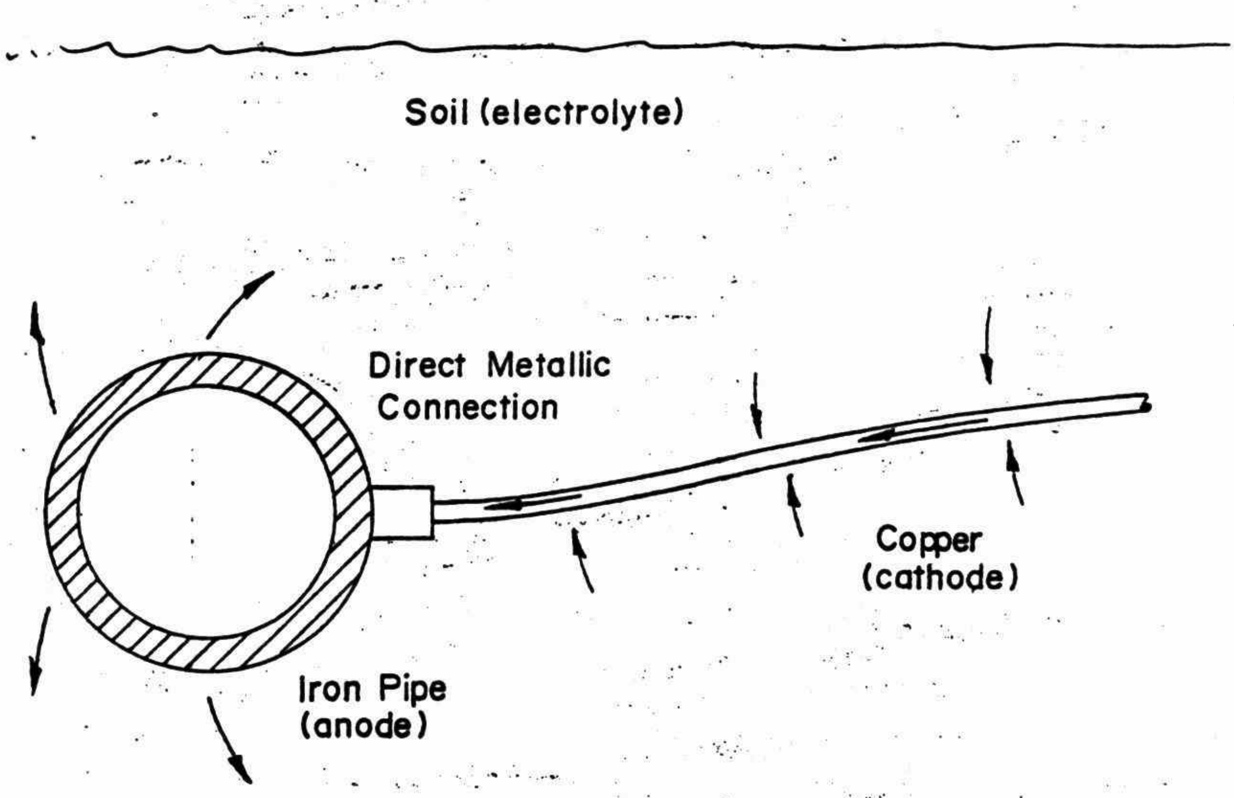


FIGURE 15-3— GALVANIC CORROSION CELL INVOLVING CONNECTION OF DISSIMILAR METALS

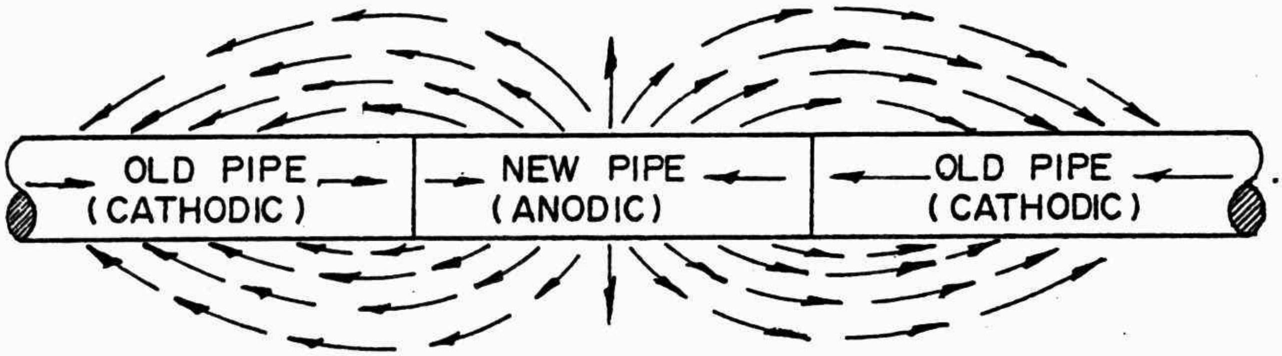


FIGURE 15-4 — CORROSION DUE TO DISSIMILAR METAL

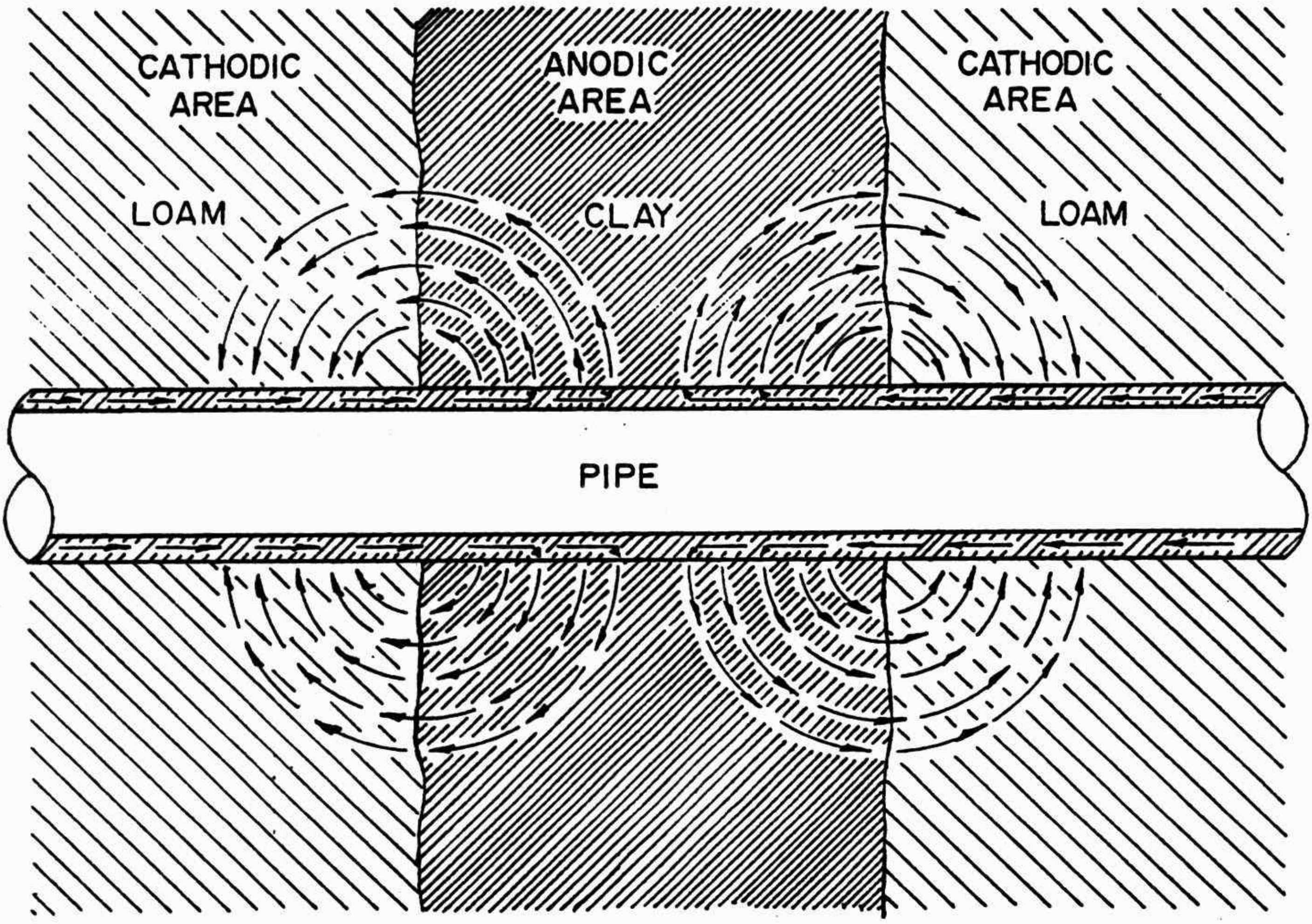


FIGURE 15-5 — CORROSION CAUSED BY DISSIMILAR SOILS

A typical corrosion cell resulting from differential aeration is shown in Fig. 15-6. When a metal structure is partially immersed in water and partially in soil, the oxygen content of the water is usually very much less than the soil. Thus a corrosion cell forms, owing to this difference in oxygen concentration, with the anode being located in the oxygen starved area. This type of cell tends to explain the appearance of corrosion on the bottom courses of storage tanks. Another common example of corrosion resulting from a differential aeration cell is the corrosion which appears at the centre of a water droplet. The centre of the water droplet is oxygen starved compared to the outer edges. The centre of the droplet becomes the anode and the edges become the cathode of the corrosion cell. Further, to some extent the oxygen concentration cell also explains pitting corrosion, Fig. 15-7. As corrosion occurs on a metal surface, the corrosion product forms a barrier to the ingress of oxygen to the base of the pit. Oxygen can readily reach the metal surface outside the pit; this surface becomes a cathode relative to the bottom of the pit which remains the anode. As long as the corrosion product remains moist and is not removed then corrosion will continue at the bottom of the pit.

Stray Direct Current Corrosion

Another major cause of corrosion on piping systems is caused by the discharge of stray direct current from the surface of the metal. Stray currents can arise from grounded DC sources such as welding operations, electrified railways and transit systems and impressed current cathodic protection systems. These currents can be particularly damaging since every ampere of current discharged from the metal surface will remove 22 lbs. of iron. Water piping systems of both the grey cast and ductile iron type are particularly susceptible to this type of corrosion on a large scale because the piping joints are usually electrically discontinuous. Consequently, a stray current

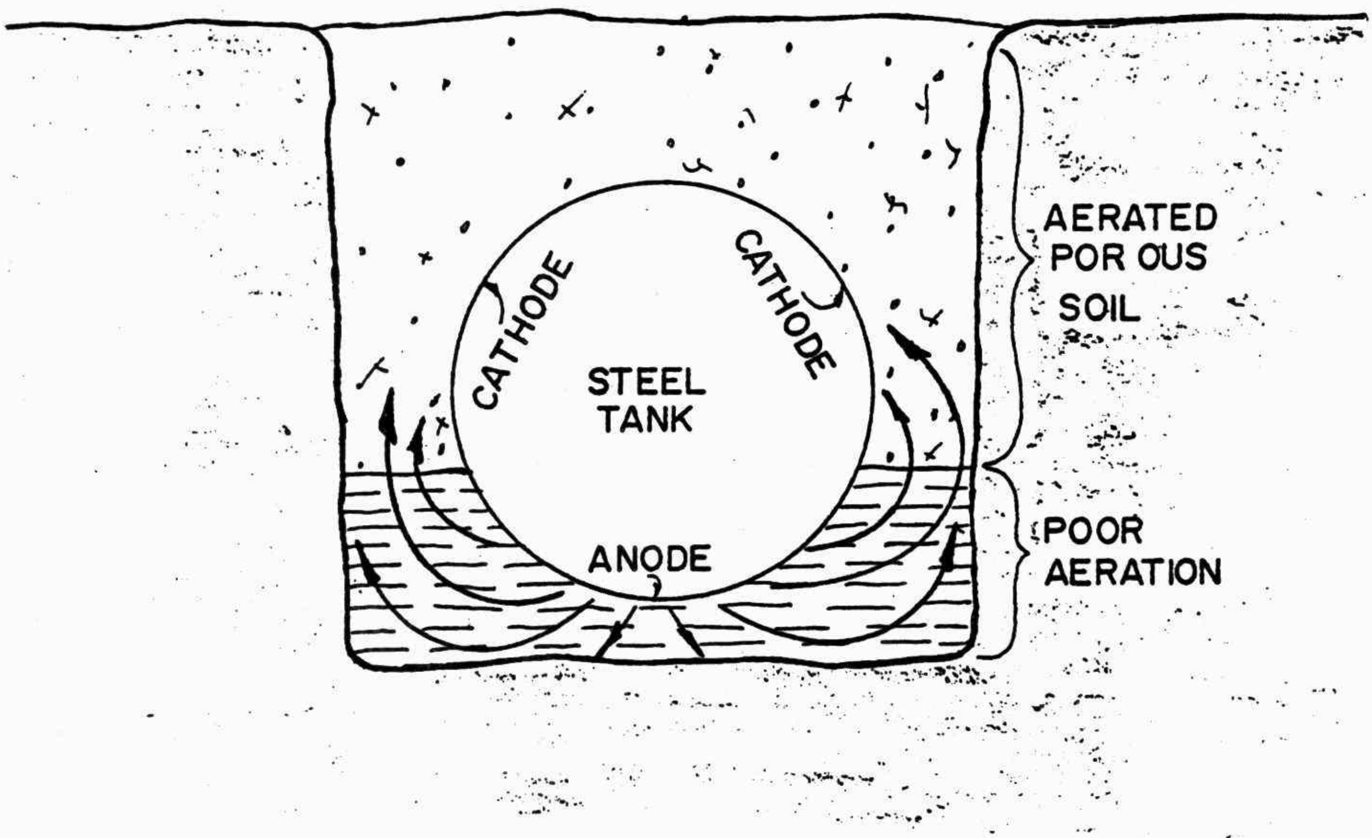


FIGURE 15-6 — CORROSION CAUSED BY DIFFERENTIAL AERATION

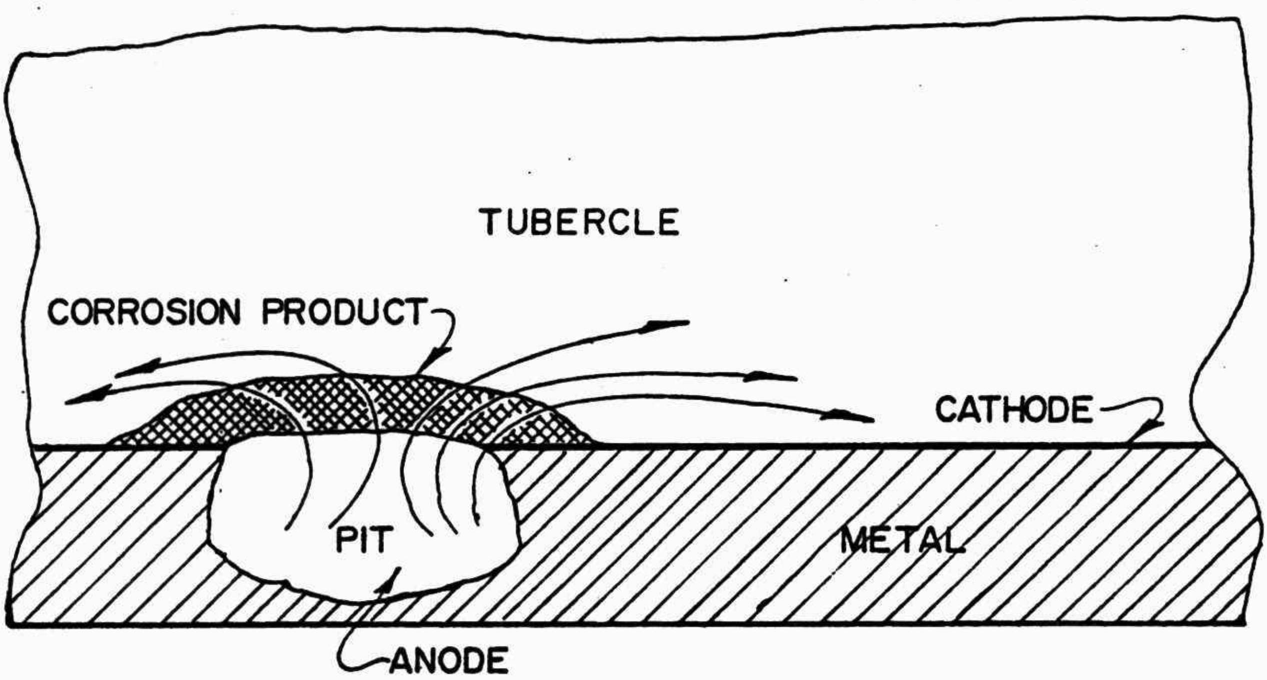


FIGURE 15-7 — PITTING CORROSION

travelling along a water piping system will discharge around each discontinuity resulting in corrosion at the rate of 22 lb per ampere year at each discharge site. Fig. 15-8 shows a typical stray current corrosion situation as a result of an electrified transit system. Here the metallic piping offers an alternative current path for the direct current returning to the substation. It is not unusual for up to 10% of all transit traction current to return by paths other than the negative rails.

Bacterial Corrosion

Although a number of different bacteria can cause corrosion of ferrous metals, by far the most common on buried piping is the desulfovibrio desulfuricans or the sulphate reducing bacteria. These bacteria thrive on anaerobic (oxygen starved) conditions and reduce inorganic sulphates to sulphides. The major cause of corrosion is reported to be a result of cathodic depolarization whereby the sulphide ions react with hydrogen at the cathodic sites on the metal surface. This results in accelerated corrosion at the anode sites where the sulphides react with the iron to produce iron sulphide.

ACCELERATING FACTORS

As we have seen the corrosion of a metal is thermodynamically promoted by Gibb's free energy and occurs in aqueous environments as a result of a number of basic causes such as differential aeration, different metals, different soils, etc. Once a corrosion cell has developed, the rate of corrosion is very important and is controlled by a number of factors.

One such factor is the electrical resistivity of the electrolyte. Sea water has an electrical resistivity in the order of 50 ohm-cms. compared with fresh water at 3,000 to 20,000 ohm-cms. Soils exhibiting electrical resistivities of less than 1,000 ohm-cms. are generally considered

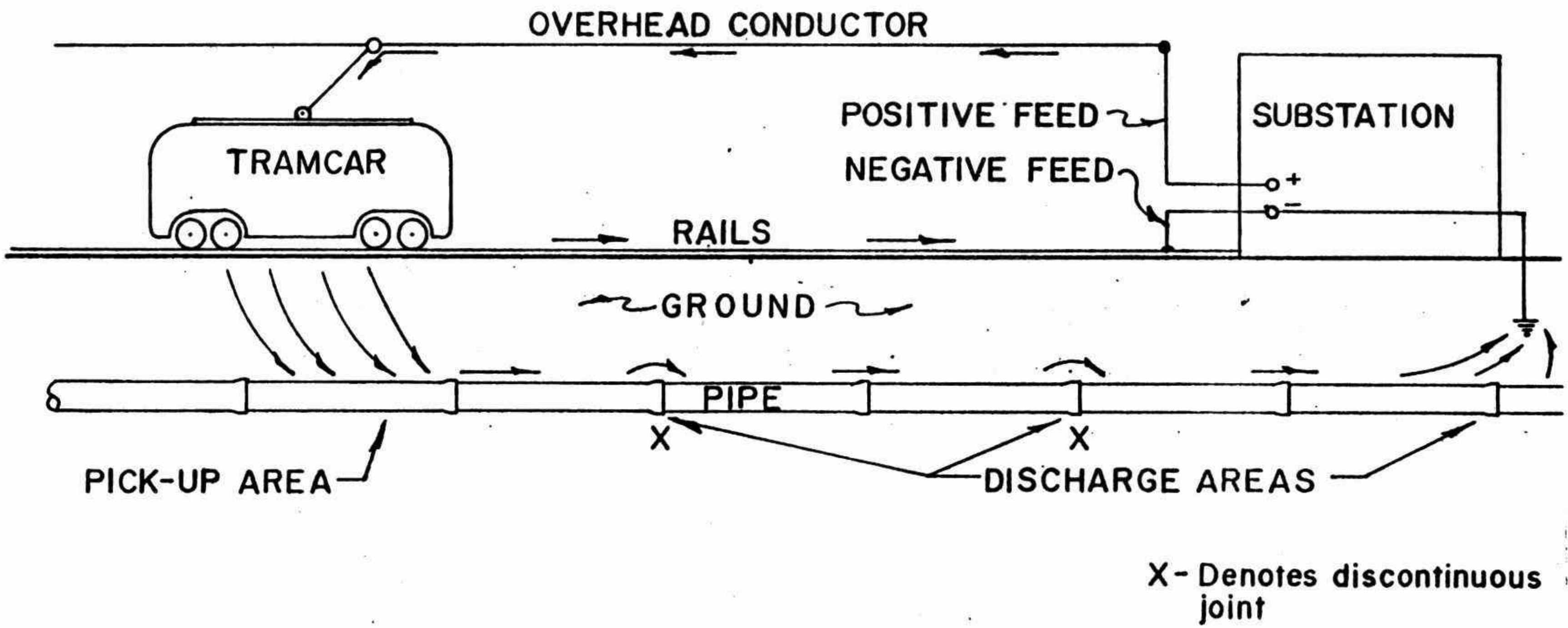


FIG. 15-8 – STRAY CURRENT CORROSION ARISING FROM AN ELECTRICAL TRANSIT SYSTEM

to be severely corrosive. In a recent study conducted in a Borough soil samples removed from pipe depth were tested for electrical resistivity. Of 114 samples, 55% were less than 1,000 ohm-cms. and only 4.5% were greater than 2,000 ohm-cms. These low soil resistivities are attributed primarily to road salt contamination. Accordingly, the same increase in corrosion must be expected on water piping systems as has already been demonstrated on motor vehicles.

A second accelerating factor is the relative surface areas of the anode and cathode. Fig. 15-9 shows the accelerating corrosion effect of increasing the cathode/anode ratio. Typically the more copper services connected to an iron main, the greater the corrosion rate of the iron main. Similarly, the smaller the piece of new replacement main with respect to the existing main, the greater the corrosion rate of the new main. This area effect has been further compounded in recent years by the tendency to install coated water piping. The coating serves only to reduce the anode areas resulting in a larger corrosion rate at the areas of coating damage.

CORROSION PREVENTION

The elements of a corrosion cell, namely; anode, cathode, electrolyte, and metallic interconnection between anode and cathode, hold the key to preventing corrosion. The removal of only one element of a corrosion cell will halt corrosion.

Protective Coatings

The application of a protective coating, so common as a corrosion prevention measure, attempts to eliminate the electrolyte in a potential corrosion cell by isolating the metal. Coatings are seldom 100% effective. They are easily damaged, thus exposing the metal substrate to the electrolyte and subsequent accelerated corrosion as previously

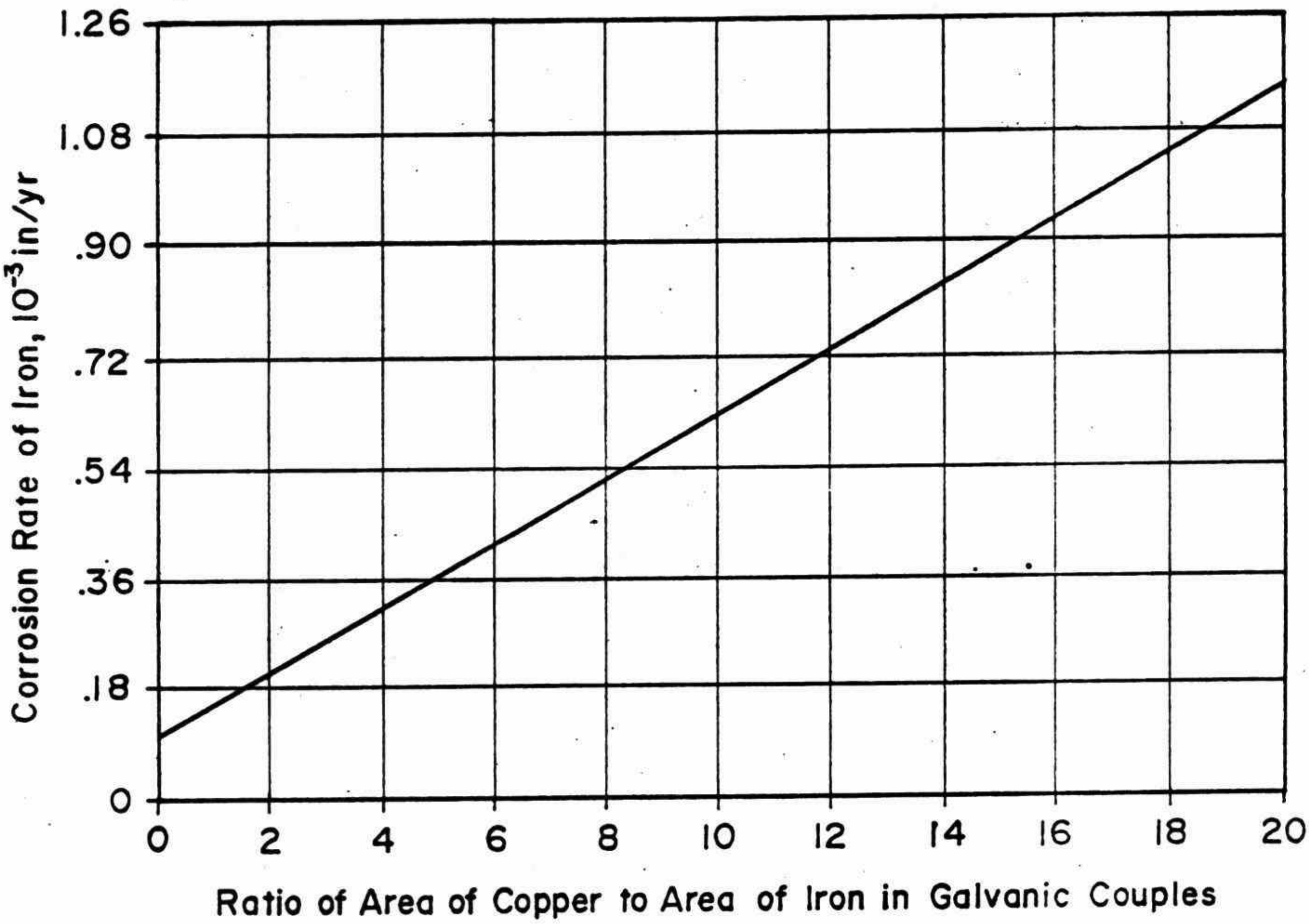


FIG. 15-9. – THE EFFECT OF CATHODE (Cu) TO ANODE (Fe) AREA RATIO IN 3% NaCl.

mentioned. The application of a protective coating to a pipeline seldom results in effective corrosion protection and in most instances results in premature failure. In fact, a protective coating should not be applied in the absence of a cathodic protection system.

Inhibitor use is a method of eliminating corrosion by treating the electrolyte so that a film is formed on the metal substrate to isolate the metal from the electrolyte. Inhibitors have practical use in closed loop systems but have no merit for buried piping.

Cathodic Protection

As stated before, elimination of one element of the corrosion cell will halt corrosion. Since the anode is the corroding element of a corrosion cell, removal of this element will result in zero corrosion. Although this cannot be done physically it can be done electrically by making the anode a cathode. This process is called cathodic protection.

It can be seen from the Galvanic Series (Table 15-1) that if a more active metal is coupled with a less active (more noble) metal, the more active metal will be the anode. Therefore, on steel structures, the steel anode can be replaced by connecting metals such as magnesium, zinc and aluminum to the steel structure so that the steel becomes the cathode of the corrosion cell. The more active metals are said to 'sacrifice' themselves to protect the steel. Hence this method of corrosion protection is called the sacrificial method.

For example, most domestic hot water tanks have a magnesium rod suspended vertically in the tank to provide enough protective current to protect the metal at 'holidays' in the glass lined coating.

Sacrificial cathodic protection is also commonly applied to well coated pipelines such as a gas distribution systems. (Fig. 15-10). A high purity magnesium casting is packaged in a special backfill and installed in the ground adjacent to the piping. Zinc and aluminum are used as anodes only in low resistivity electrolytes such as sea water. The sacrificial method has a small current output and is only applicable to well coated and isolated structures or to bare structures where localized protection is achieved.

Where large cathodic protection currents are required, cathodic protection is achieved by the impressed current method using a rectifier source to provide power to a ground bed consisting of semi-inert anode materials such as graphite and high-silicon cast iron. Fig. 15-11 shows a typical application of the impressed current method on a pipeline.

Cathodic protection, unlike other forms of corrosion prevention such as coatings, can be 100% effective providing the steel structure voltage is moved in the negative direction so that it is more negative than -0.850 volts. Cathodic protection costs can be substantially reduced by coating the structure to be protected. In fact, coating of pipelines should only be done when it is intended to install cathodic protection.

CORROSION PREVENTION ON WATER DISTRIBUTION PIPING

There are two distinct and separate considerations in corrosion prevention of water distribution piping, namely; existing piping and future piping additions.

Existing Piping Systems

Existing piping systems can seldom be cathodically protected using impressed current cathodic protection since

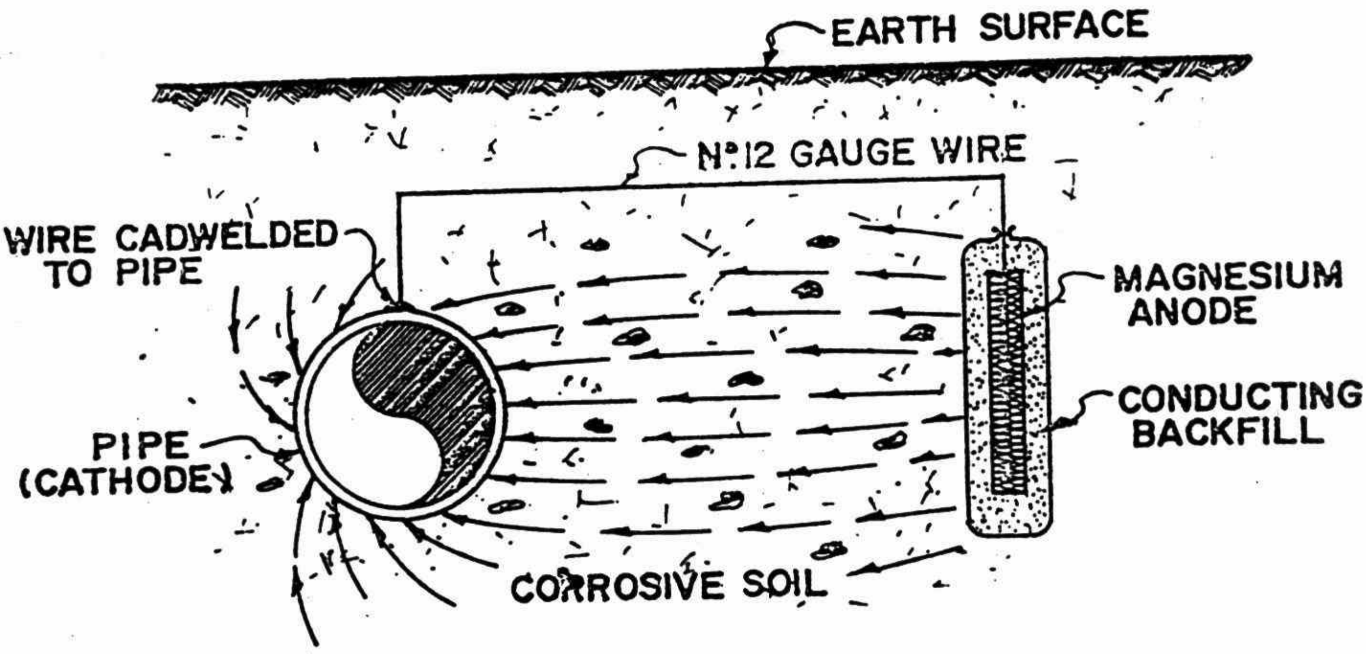


FIGURE 15-10-SACRIFICIAL CATHODIC PROTECTION

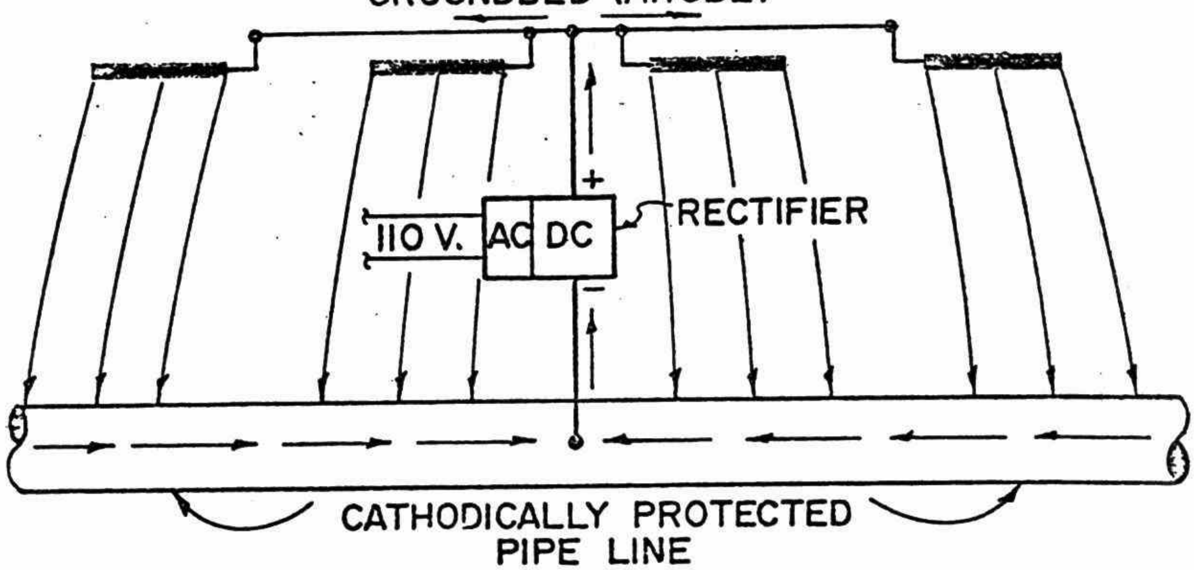


FIGURE 15-11 - IMPRESSED CURRENT CATHODIC PROTECTION

electrical discontinuities at joints promote the likelihood of stray current corrosion. Therefore, the sacrificial method is the only alternative, but because of the low current output of these anodes, many anodes would be required to protect the entire exising piping.

A more reasonable and economical approach is to identify the areas of high failure incidence and treat these areas by the addition of sacrificial anodes at the time of failure repair when the excavation is open. Although this procedure called 'hot-spot' protection will not result in complete protection of the entire piping system it will result in localized protection. Accumulated failures as a result of corrosion are usually logarithmically increasing with time, as shown in Fig. 15-12. By the application of 'hot-spot' protection the expected logarithmic curve can be flattened so that the overall failure frequency doesn't climb so dramatically.

Magnesium anodes are generally used in a 'hot-spot' program although zinc anodes can be used where the soil resistivity is low (less than 1000 ohm-cms.) providing the zinc anodes are packaged in a prepared backfill similar to that used with magnesium anodes.

New Piping Systems

New piping systems, intended for installation in regions of known stray current activity should be made of non-metallic materials such as asbestos-cement, PVC etc. Where metal fittings and/or services are connected to non-metallic piping, these should be coated and cathodically protected using small sacrificial anodes. Particularly important in this regard are copper service lines. In iron water distribution systems, the copper services are normally cathodic to iron mains and therefore seldom fail from corrosion. However, once the iron main is no longer connected, the copper is subject to soil corrosion and merits the application of a sacrificial anode.

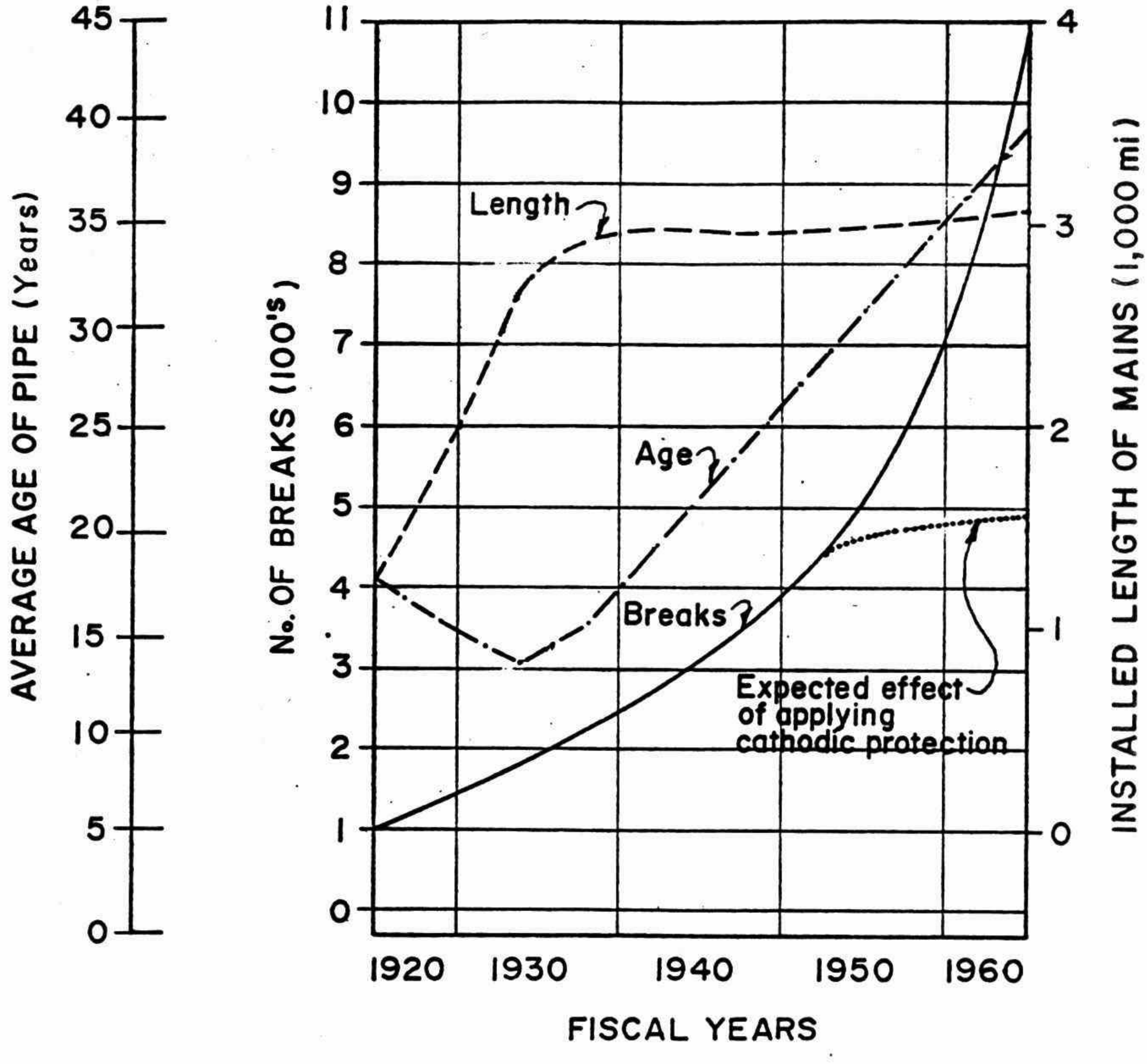


FIG. 15-12 – CAST-IRON MAIN BREAKS IN DETROIT, 1920-60

Where new water distribution systems are of the ductile iron type, the piping should be well coated (e.g. with a pipeline grade coating such as extruded polyethylene) and the joints should be made electrically continuous by the provision of continuity devices such as bond straps, conductivity screws, etc. Further each copper service should be isolated from the iron main using a dielectric fitting.

By following the foregoing procedure the corrosion engineer now has the option of designing either a sacrificial or impressed current cathodic protection system. Further, the entire piping system can be economically protected since it is well coated and electrically isolated. This same procedure has proved successful in gas distribution systems.

IMPLEMENTING A CATHODIC PROTECTION PROGRAM

Before any corrosion prevention program can be implemented, waterworks personnel must become cognizant of the part corrosion plays in main failures and then must be aware of the economical benefits of cathodic protection.

Most municipal utilities are unfamiliar with the application of cathodic protection. Hence, when embarking on a cathodic protection program a corrosion consultant should be retained to design the systems and to assist in implementing maintenance programs. All cathodic protection designs should be done only by an NACE accredited "Corrosion Specialist" who is also a registered Professional Engineer. Properly designed cathodic protection programs, after an introductory period of time, can usually be carried out by the utility personnel with only occasional advice from the consultant.

Waterworks engineers should also take out membership in NACE which actively publishes corrosion prevention standards and papers providing up to date corrosion

prevention technology.

SUMMARY

The waterworks industry is no doubt faced with ever increasing corrosion failures of aged cast iron piping and of the thinner wall ductile iron piping. Cathodic protection can offer an effective economic solution to corrosion prevention on both existing and new piping systems. However, a cathodic protection program should only be implemented with the counsel of a corrosion consultant.

REFERENCES

1. Arnold, Gerald E. - Experience with Main Breaks in Four Large Cities - (Philadelphia). Jour.A.W.W.A., August 1960.

2. Niemeyer, Howard W. - Experience with Main Breaks in Four Large Cities (Indanapolis). Jour.A.W.W.A., August 1960.

3. Fitzgerald, John H. - Corrosion as a Primary Cause of Cast-Iron Water Main Breaks. Jour.A.W.W.A., August 1968.

4. Romanoff, Melvin - Underground Corrosion. NBS Circular #579, 1957, p.75.

5. Brasunas, Anton De S and Hammer, N.E. - The Scope and Language of Corrosion. Chapter 1, p.1. NACE Basic Corrosion Course.

6. Evans, U.R. - The Corrosion and Oxidation of Metals - London, Edward Arnold Ltd., p.15.

7. Scully, J.C. - The Fundamentals of Corrosion. Pergamon Press, p.3.

8. Peabody, A.W. - Control of Pipeline Corrosion. NACE - Chapter 2,p.5.

9. Warren P. Inverson - Anaerobic Corrosion of Mild Steel by Desulfovbrio. Institute of Materials Research NBS, NACE Conference, 1969, Paper #48.

10. Various Authors - Anticipated Corrosion of Steel Exposed to Soils of Varying Resistivity. Australasian Corrosion Engineering Nov./Dec. 1974, p.22.

11. Staehle, R.W. - Galvanic and Stray Current Corrosion: Causes and Prevetnion. Ohio State University, p.9.

12. Remus, Gerald J. - Main Breaks - Detroit - Journal AWWA, August 1960.

SUBJECT:

WATER DISTRIBUTION
SYSTEM OPERATIONS

TOPIC: 16

Plans and Records

OBJECTIVES:

The trainee will be able to

1. Understand the importance of permanent plans and records
2. Recall the basic elements of a comprehensive plan and record system and the purpose of each.

PLANS AND RECORDS

INTRODUCTION

This paper will deal with "Permanent Plans and Records" pertinent to the Operating Staff in a Utility. No Water Utility can operate efficiently without a well maintained permanent record system. No Operating Personnel can work effectively if he does not understand the Plans and Records System.

Efficient operation of a distribution system requires that the superintendent or manager, have before him an accurate picture of the whole system he operates. A "Comprehensive Map" or "Operating Map" will enable him to determine which areas are inadequately supplied and why, whether the mains in an area are capable of supplying the water which might be required to fight a major fire, if fire hydrants are improperly spaced, where trouble should be looked for when pressures are found to be below normal and to determine new feeder main routes.

The Distribution System operating staff, in their daily operation of the water system, requires records that show in proper detail the location and valving for existing and future systems. This map should show the size of all mains active or inactive, their location, valves and fire hydrants shown and numbered, and any other operating information. This type of record is called a "Section Map".

Additional records are still required by the Operating Staff. They should have small sized maps showing the layout of the distribution mains. As part of their equipment, complete sets of valve measurements covering the districts in which they work are necessary if valuable time

is to be saved in making valve closures. Residential services and their curb stop locations can be recorded in a book form and copies kept with each crew. Large size services (over 3/4" dia..) also can be kept in book form, and here the route, size and materials are recorded as well.

Other records, are kept in the office. These include valve records, hydrant records, records of leaks and main breaks, as constructed drawings of work orders, inspector's reports (new watermain construction), photographs.

No matter what size the Utility may be, record keeping is a time consuming chore. The Engineering Department must be responsible for the large maps to be brought up-to-date accurately, but operating staff can help by filling out field forms and records neatly and accurately so they will form the permanent records themselves. Use "still cameras" to record an installation, e.g. "Polaroid" Cameras. Valve and hydrant field maintenance sheets can be stapled to their respective cards. It's recorded once and correct. Use it that way.

Microfilming has become more common for record keeping and availability. Since the records and plans have been photographically reduced, the microfilm allows easy storage and retrieval within the cab of a crew vehicle. Many utilities are adopting microfilming as a standard records tool.

Each Utility should prepare a "standard practice" to apply to its own procedure of keeping distribution system records. All phases of record keeping should be enumerated and described so that anyone in the organization can, by referring to the standard practice, know how to prepare, find or interpret any of the distribution system records.

The following paragraphs suggest a format of permanent maps and records for use in the Water Industry.

SYMBOLS

The need for some degree of standardization of symbols used on mapped distribution system records is desirable. Each mapped record tells a story which could be made clearer, if the language used was based upon an alphabet familiar to a person endeavouring to read the record. Standardization of symbols between Utilities is not necessary. Symbols must be simple in design, easily drafted, and their function understood.

The symbols shown at Figures 16-1 and 16 -2 are suggested as a guide to be followed on various types of mapped records. The symbols shown on Figure 16 -1 are those from the A.W.W.A. M8 Water Distribution Training Manual. The other figure has symbols that were adopted by the Region of Halton.

MAPPED RECORDS

Details on drafting techniques, types of tracing paper, ink, lead pencil will not be dealt with, since the Engineering Group will have skilled personnel to handle this part. The operations staff must have the up-to-date copies, know what they represent, how to use them and mark them up when required.

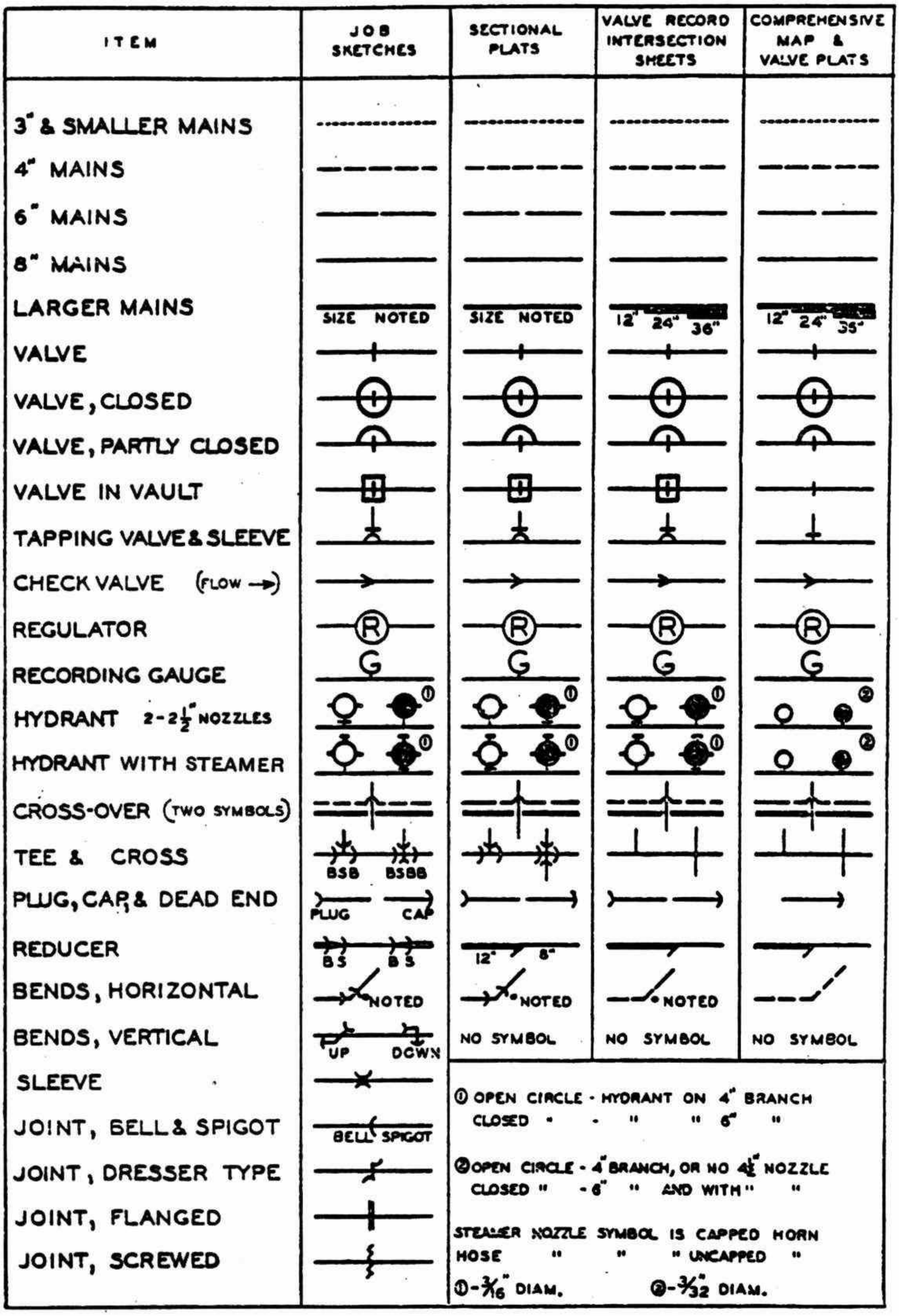


Figure 16-1 Symbols

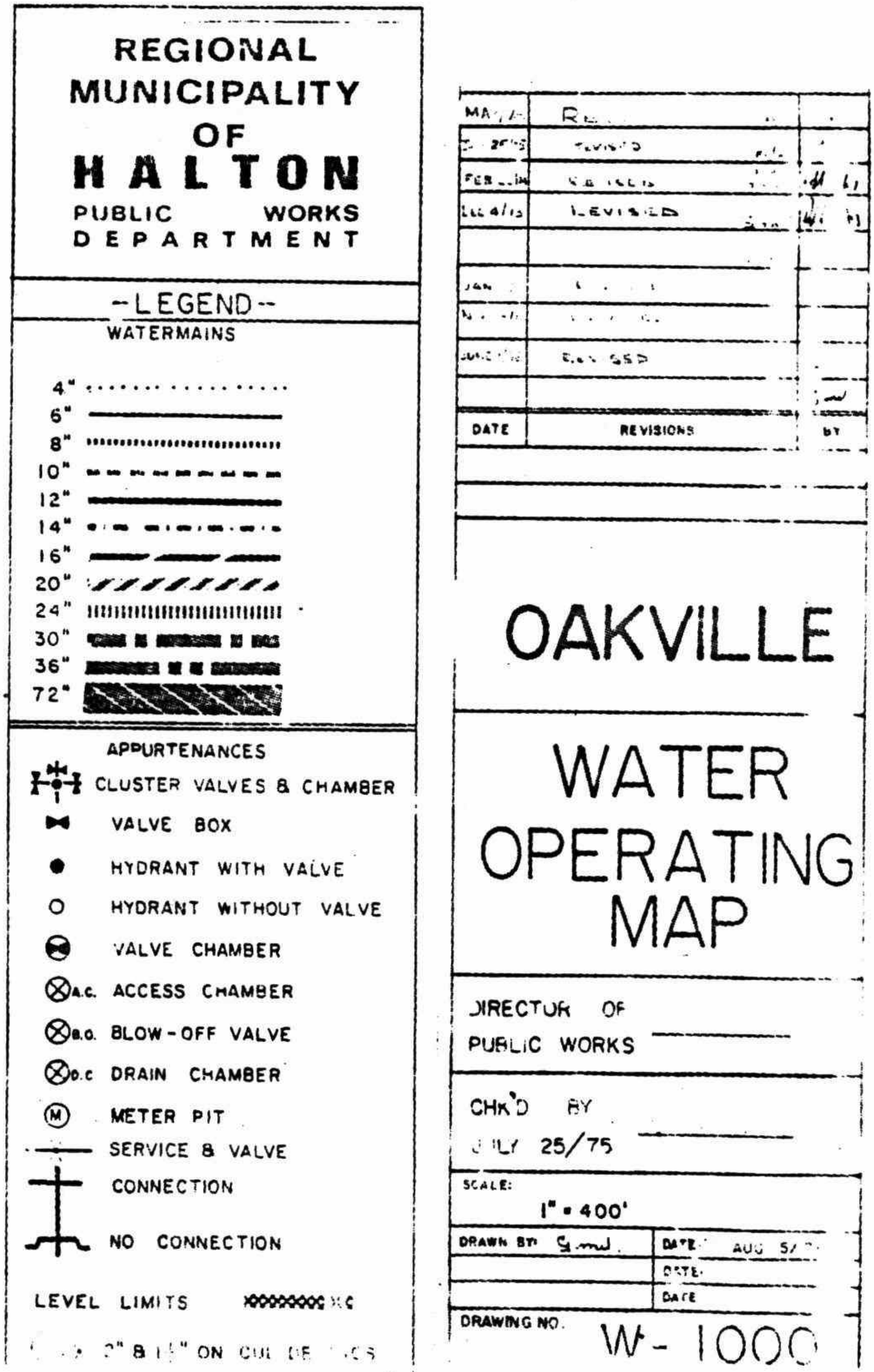

REGIONAL MUNICIPALITY OF HALTON
PUBLIC WORKS DEPARTMENT
-LEGEND-
WATERMAINS
4"
6"
8"
10"
12"
14"
16"
20"
24"
30"
36"
72"
APPURTENANCES
CLUSTER VALVES & CHAMBER
VALVE BOX
HYDRANT WITH VALVE
HYDRANT WITHOUT VALVE
VALVE CHAMBER
A.C. ACCESS CHAMBER
B.O. BLOW-OFF VALVE
D.C DRAIN CHAMBER
M METER PIT
SERVICE & VALVE
CONNECTION
NO CONNECTION
LEVEL LIMITS
DATE
REVISIONS
BY
OAKVILLE
WATER OPERATING MAP
PUBLIC WORKS
CHK'D BY
25/75
SCALE:
1" = 400'
DRAWN BY
DATE
DATE
DATE
DRAWING NO.
W-1000

Figure 16-2

COMPREHENSIVE MAP OR OPERATING MAP

The function of this record is to show a clear picture of the entire water distribution system in diagramatic layout. It is primarily an operating record of value to the superintendent and construction engineer. It should be drawn in such fashion as to indicate readily the areas adequately piped, the sections which suffer through lack of large mains, the place where short extensions will eliminate dead ends, where many fire hydrants are installed in congested districts, and where mains are inadequate to support them in case of a major fire. Secondarily, it is a record of water system physical assets.

Since the main function of this record is to form a clear picture of the watermain system, all distracting information is omitted. Street or property lines should be deleted, - cut down on confusion lines. Insignificant items should be left out. Line thickness should be employed to represent different main sizes so that the larger mains with greater carrying capacity will be easily spotted. Important connections at intersections can be shown diagrammatically at a larger scale.

The scale should be as large as possible, using a map preferably 1060 mm (42 in.) wide (standard roll width). A scale of 1:5000 (1" = 400 ft.) was found to be convenient in Halton Region. Scales somewhat smaller e.g. 1:10,000 (1" = 800 ft.) or 1:12,000 (1" = 1,000 ft.) requires very careful drafting. Don't let this map become a showpiece pasted on a wall. It was meant to be used; put in map tacks, colour areas, show changes in red pencil.

Figures 16-3, 16-4, and 16-5 are examples of a Comprehensive Map or Operating Map.

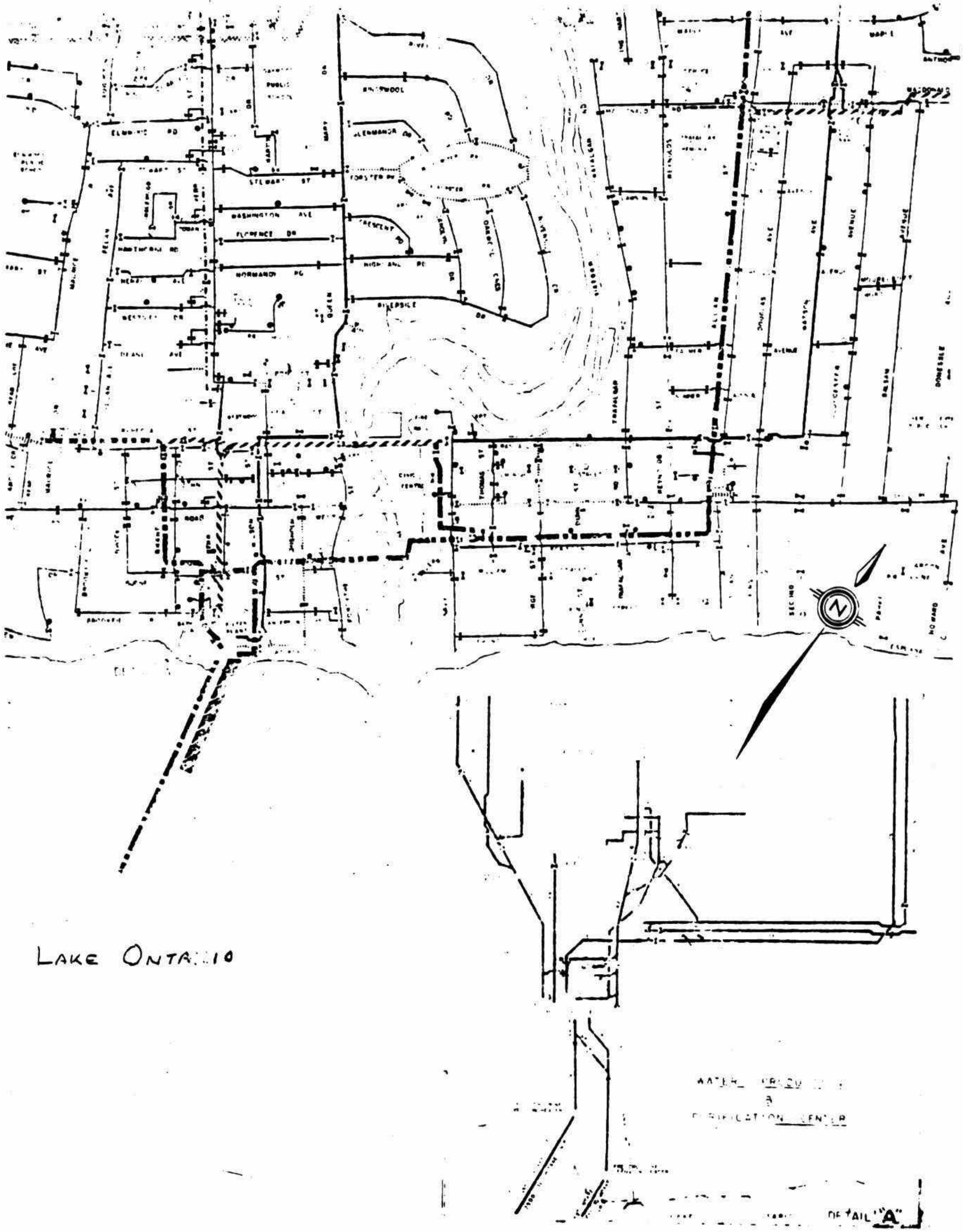


Figure 16-3

PORTION OF OAKVILLE
WATER OPERATING MAP
(REDUCED SCALE)
(ORIGINAL IS 1" = 400 ft.)

REGIONAL
MUNICIPALITY
OF
HALTON
PUBLIC WORKS
DEPARTMENT

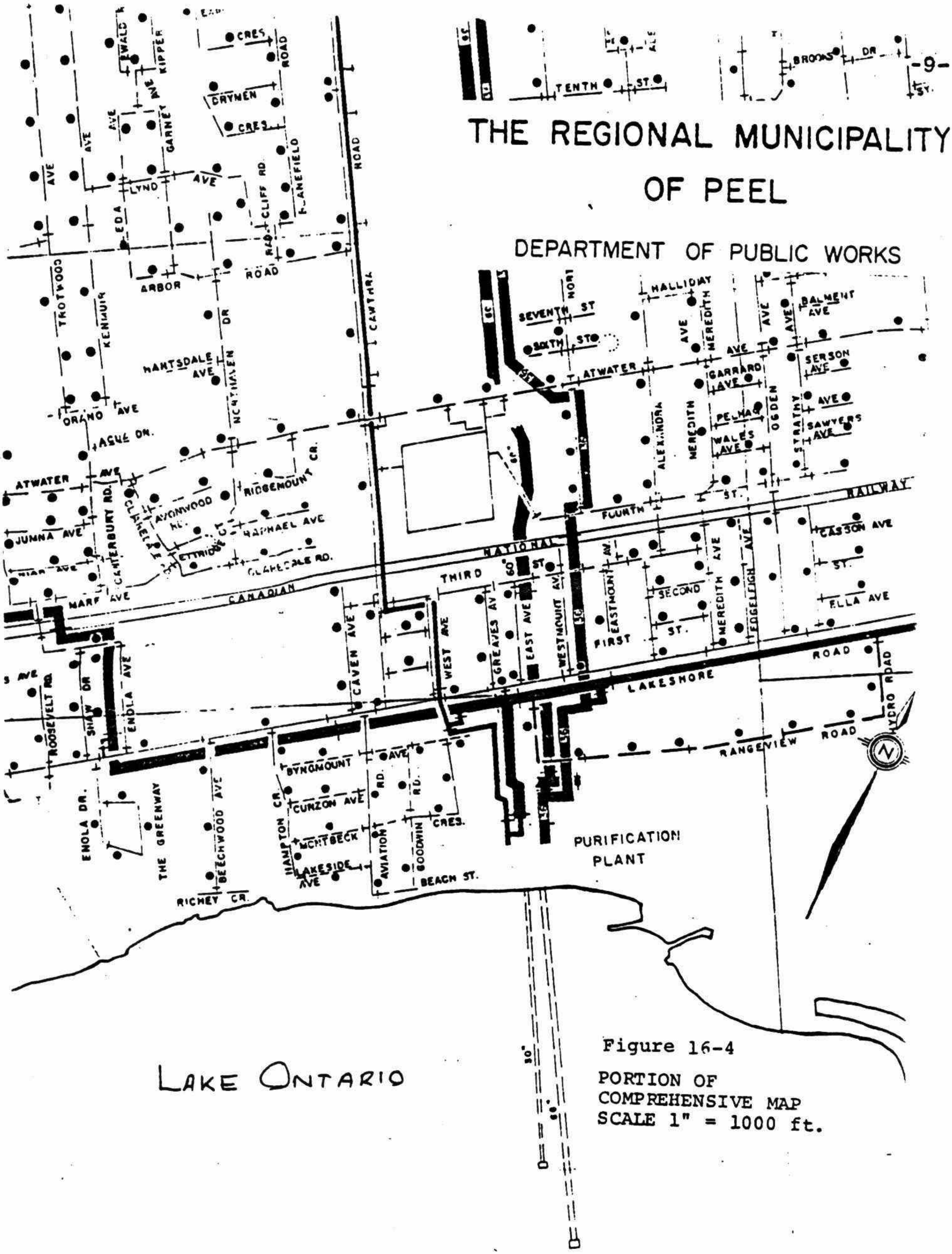


Figure 16-4

PORTION OF
COMPREHENSIVE MAP
SCALE 1" = 1000 ft.

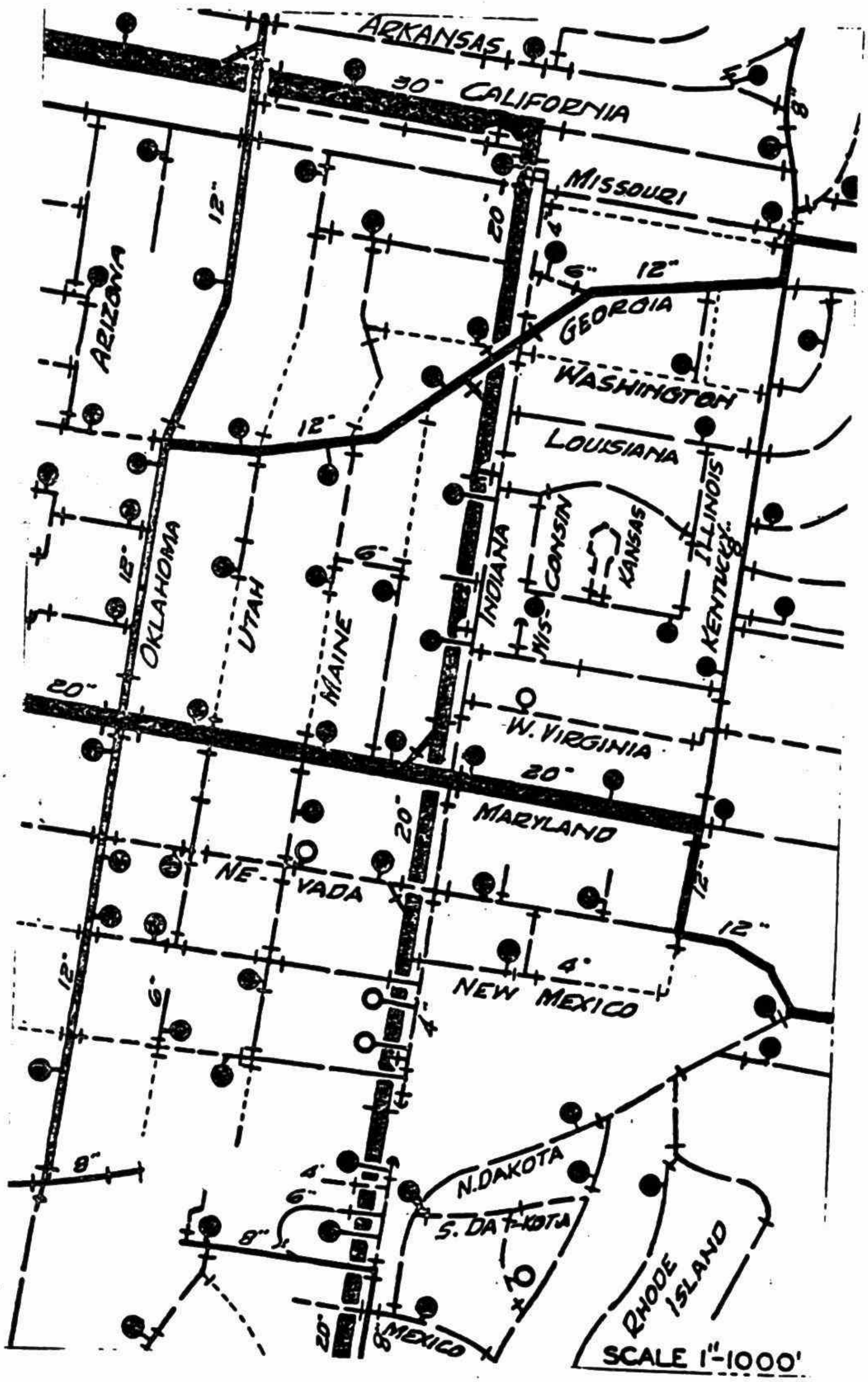


Figure 16-5 Portion of comprehensive map

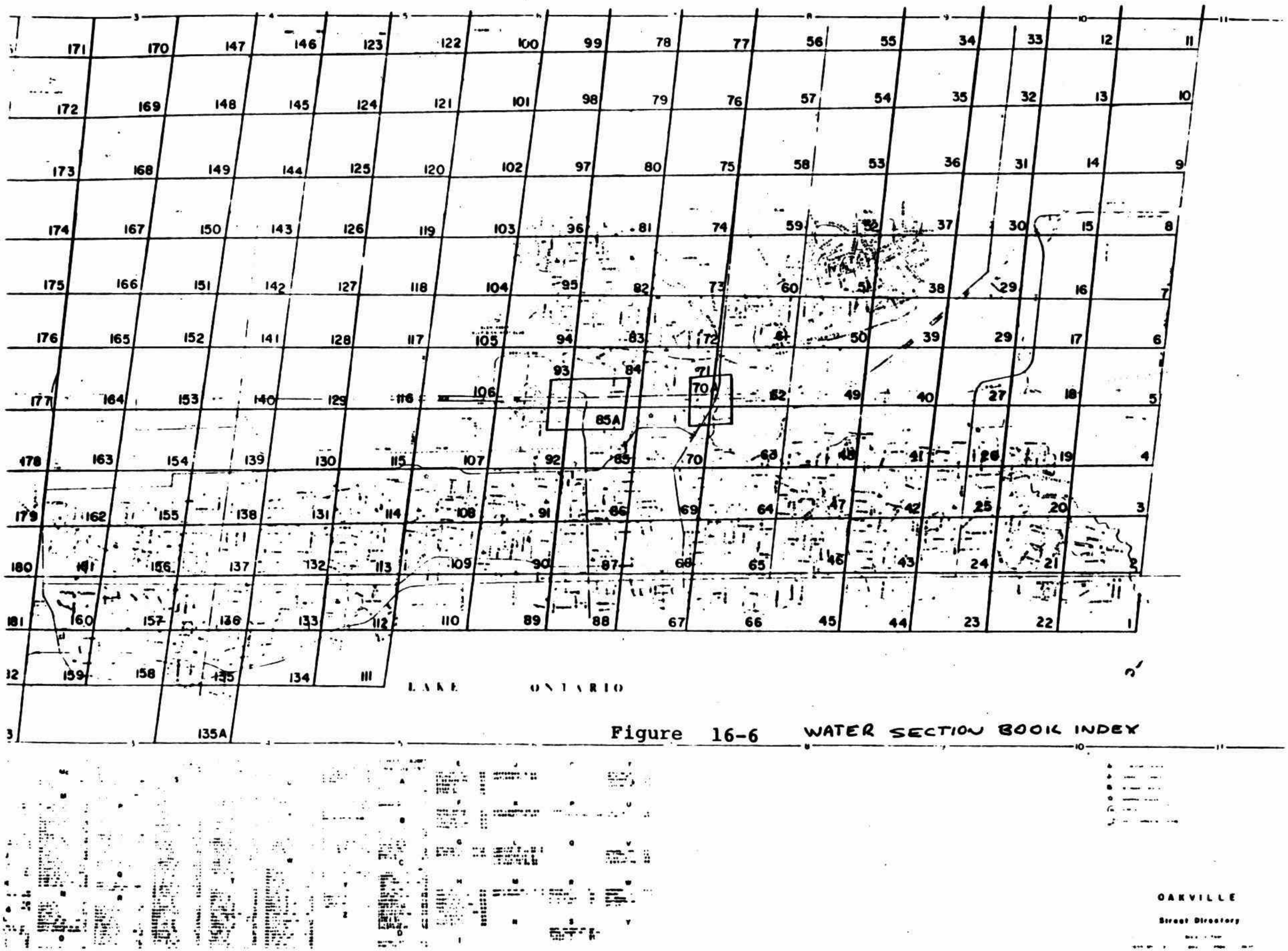


Figure 16-6 WATER SECTION BOOK INDEX

SECTION MAPS

This record should be considered as the complete mapped record of the distribution system structures. It is the detailed account of the distribution system assets. Since it must be at much larger scale than the comprehensive or operating map, this record must usually be in sections; hence the term.

The comprehensive map should be used as the base for the "section map". North-South and East-West coordinates should be drawn on a print of the comprehensive map corresponding to the size of 1:1200 (100 ft.) scale "section map". The spaces should be numbered like a road map eg. 1,2,3, etc. from North to South and lettered A,B,C, etc. from East to West. Avoid overlaps, section off an area where the boundaries cut between streets, not through the Centre of a street. An index (Figure 16-6) is required.

Each section map should butt up against the adjacent map on all four sides.

Copies of these maps should be made up in a book form. Here again the copies are meant to be used; additions and corrections by both the operating staff and engineering department should be made in some contrasting colour as work reports are completed.

Items to be Shown on "Section Maps"

1. Map designation or number

2. Adjacent Map Numbers

3. Street Names and Width

4. Mains and Sizes
5. Material to Main
6. Years Mains were Installed
7. Work Orders of Main Installations
8. Distance from Property Line
9. Fire Hydrants, Numbers and Classifications
10. Valves and Numbers
11. Valve Sheet designation shown in margin
12. Intersection numbers (if valve intersection maps are used)
13. Block Numbers
14. Lot Numbers
15. House Numbers
16. Water Account Numbers
17. Measurements to Service Lines
18. Sizes of Taps
19. Size and Materials of Service Lines
20. Distances, Main to Curb Stop
21. Distances, Curb Stop to Property Line or Building
22. Distance, to angle points
23. Distances, to fittings
24. Dead Ends and Measurements
25. Last Revision Date
26. North Arrow
27. Scale

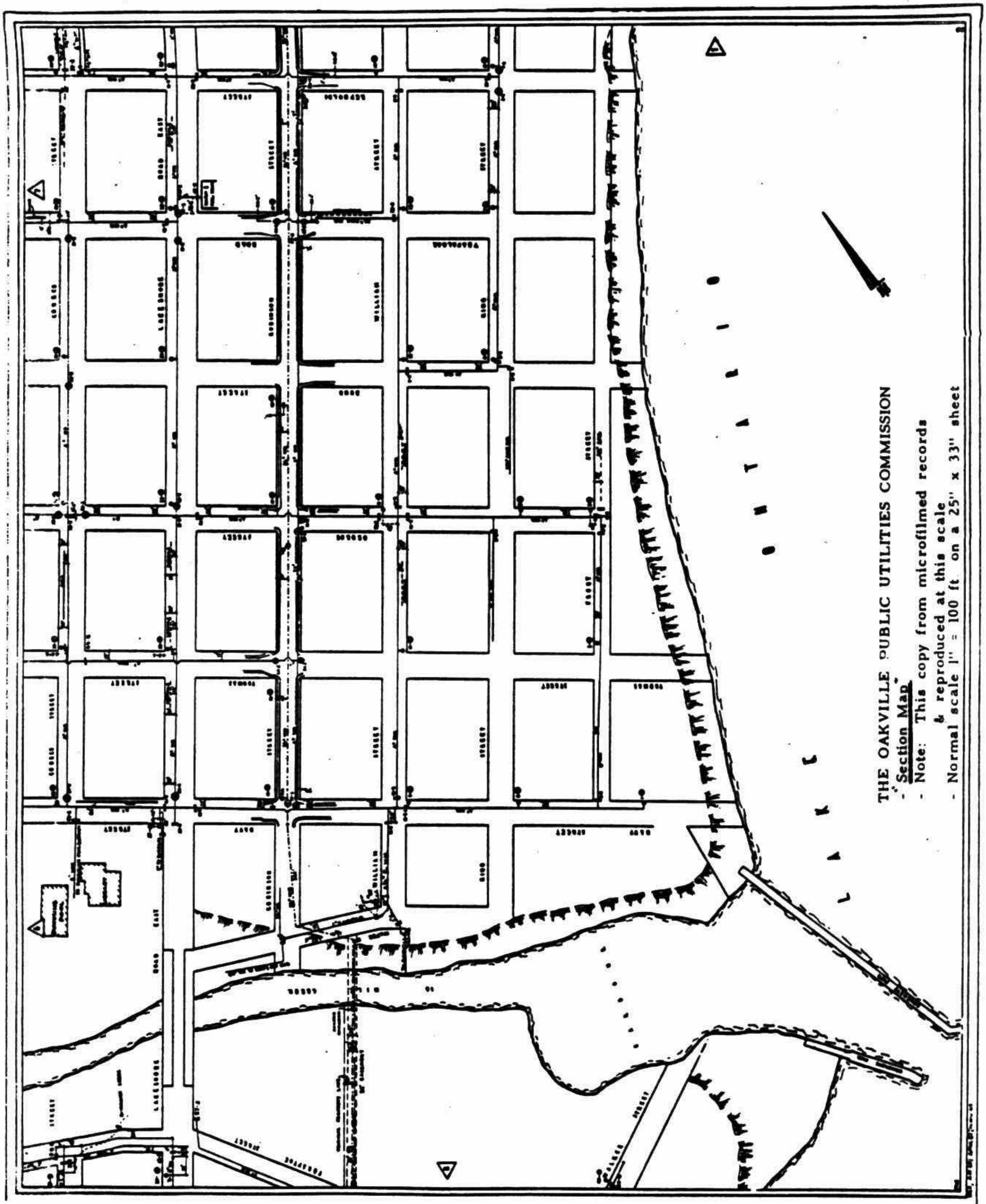


Figure 16-7 -- Section Map

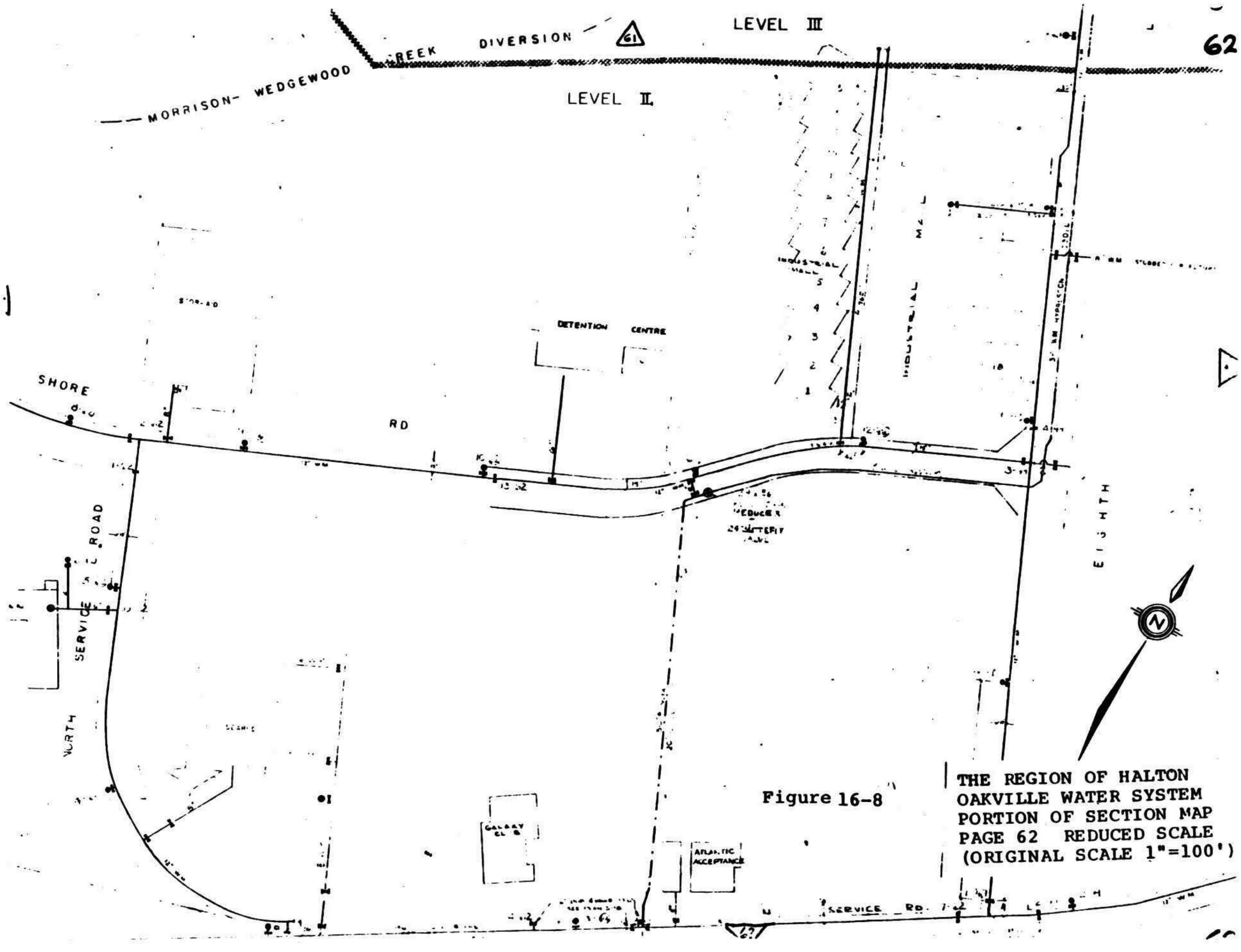


Figure 16-8

THE REGION OF HALTON
OAKVILLE WATER SYSTEM
PORTION OF SECTION MAP
PAGE 62 REDUCED SCALE
(ORIGINAL SCALE 1"=100')

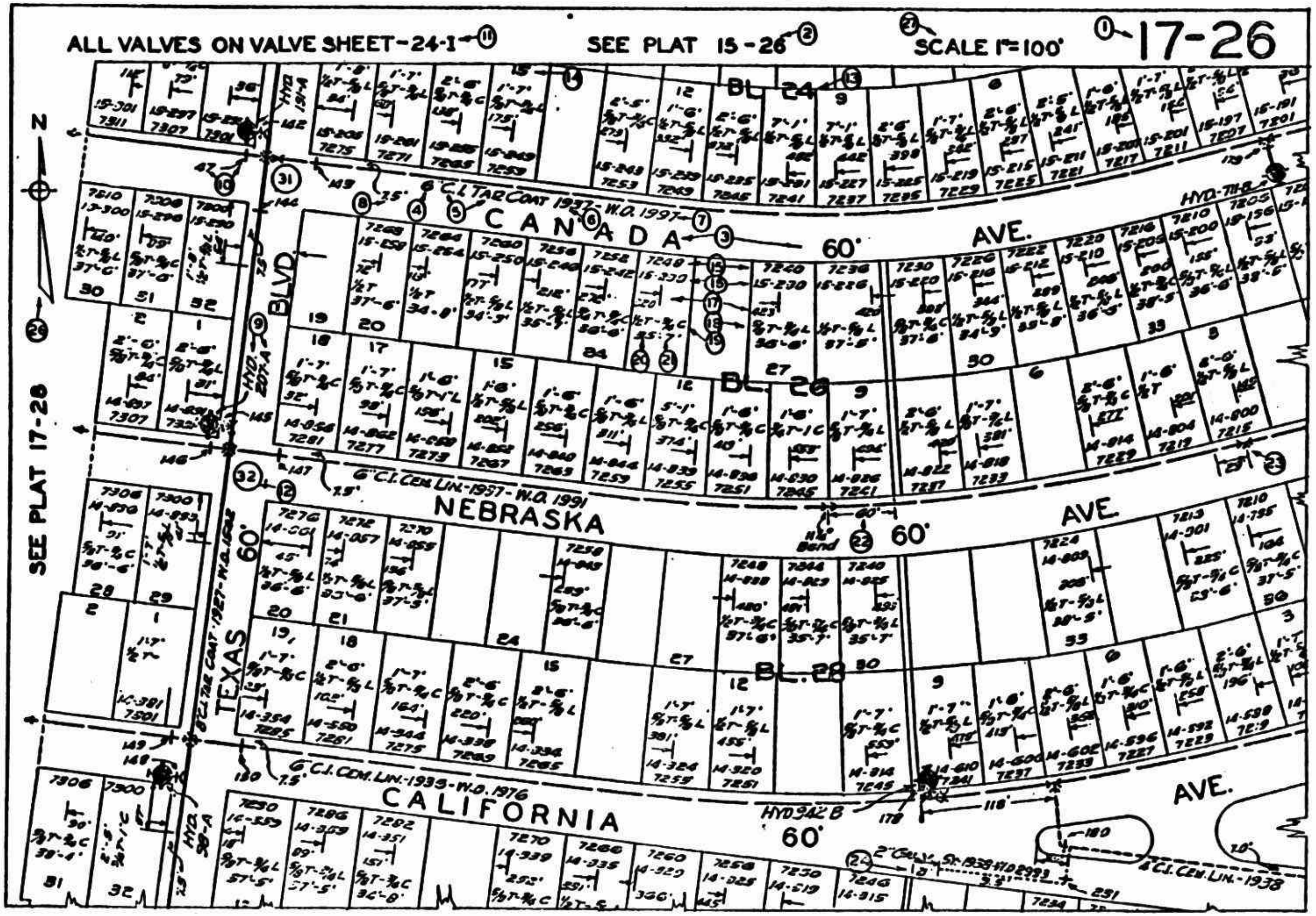


Figure 16-9 Portion of Sectional Plat

Figures 16-7 and 16-8 show a "section map" at a reduced scale. Figure 16-7 was formed from microfilmed records to the size illustrated. Copies of these maps are in a book form and are part of the tools in each vehicle of that Commission. Figure 16-9 is an extract from the AWWA Manual.

VALVE RECORD

Valves play such an important part in the operation of a distribution system that a separate record of them is warranted. To be of greatest value, this record should be kept in a manner which will allow copies to be carried by the operating staff. This record must show measurements from permanent reference points to each valve so that it may be readily located. The record should also give current factual information about each valve, eg. the direction to open; the type or valve, the make, and date installed.

Several satisfactory methods of keeping these valve records are used by Water Utilities. Two of the common ones are as follows:

1. "Map and List" Record

2. "Inter-Section Sheet"

"Map and List" Record

Each map shows a section of the distribution system at a scale of 1:6000 (1" = 500 ft.) covering an area 120 m x 150 m (4,000 ft. x 5,000 ft.) on a 254 mm x 354 mm (10" x 14") sheet. This would be the same area as shown on four of the sectional maps described earlier.

On an intersection map are shown the street names, mains and their sizes, valves with numbers, and hydrants. On an opposite page or pages is shown the valve information; valve number; principal street with reference measurements

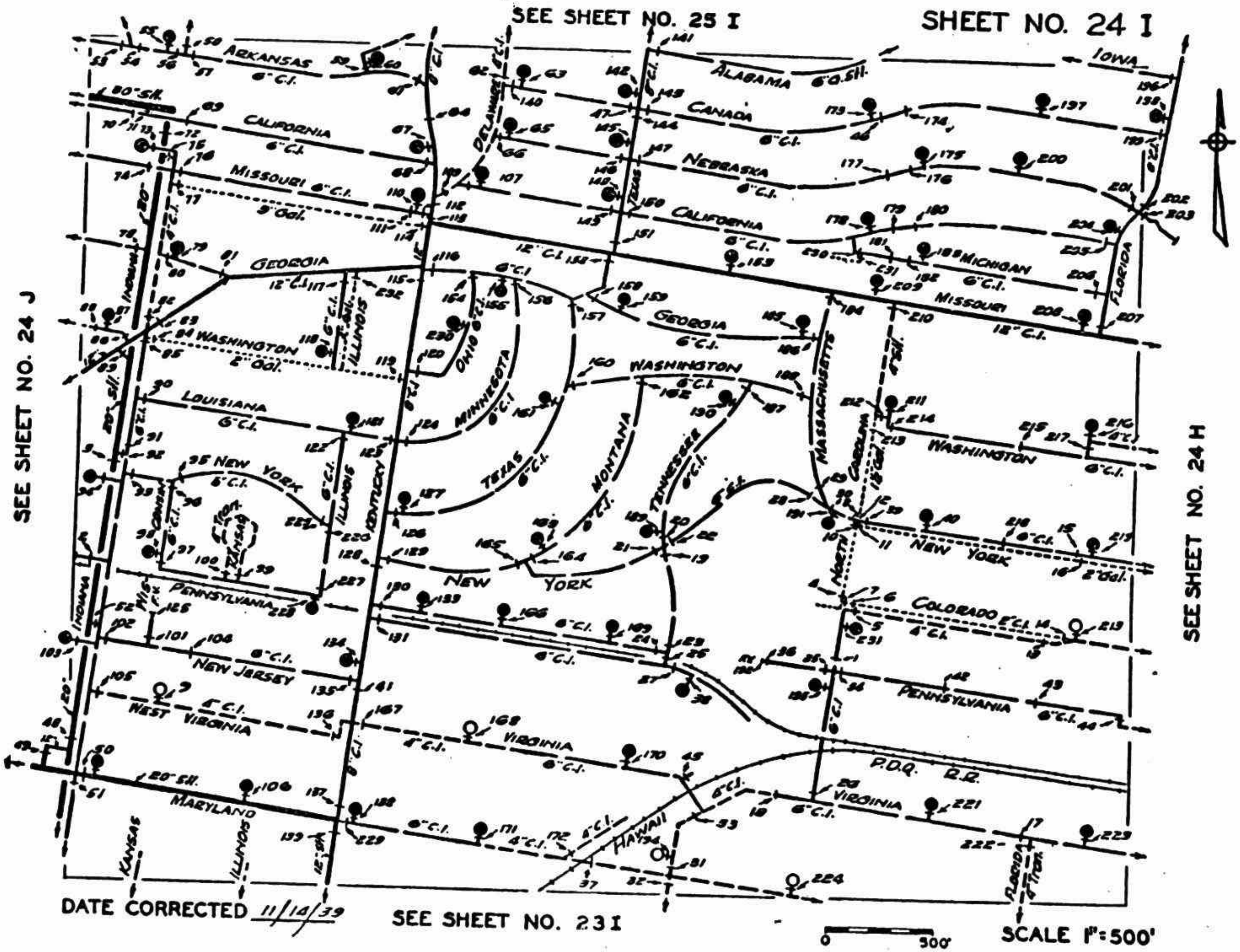


Figure 16-10 - Valve Plat

SHEET NO. 24 I

VALVE NO.	PRINCIPAL STREET	DISTANCE FT.	DIR.	REFERENCE	INTERSECTING STREET	DISTANCE FT.	DIR.	REFERENCE	SIZE	MAKE	OPEN	TURNS	DATE SET	REMARKS
1	North Carolina	11	W	E side E walk	Pennsylvania	12	N	N side N walk	6	A.R.C.	L	12	[illegible]	
2	Pennsylvania	1½	S	N R	Indiana	12	E	W R	6	A.R.C.	L	12	[illegible]	Bal Tap
3	Indiana	6½	E	W R	New York	[illegible]	N	N R	20	[illegible]	L	42	1921	
4	North Carolina	11	W	E side E walk	Colorado	3	N	N side N walk	2	A.R.C.	-	THd	[illegible]	
5	Colorado	12	N	S side S walk	North Carolina	3	E	W E side E walk	4	Cha	L	9	[illegible]	
6	Colorado	22	S	N side N walk	North Carolina	11	W	E side E walk	2	Cha	-	THd	[illegible]	
7	Colorado	22	S	N side N walk	North Carolina	10½	W	E side E walk	2	Cha	-	THd	[illegible]	
8	New York	7½	S	N side N walk	North Carolina	13½	W	E R priv. Rd.	2	[illegible]	-	THd	[illegible]	
9	West Virginia	7¾	S	N side N walk	Indiana	22½	E	W R [illegible]	6	[illegible]	L	18	[illegible]	6' S W of Hydrant
10	New York	15½	S	S side S walk	North Carolina	11½	W	W E side E walk	2	[illegible]	-	THd	[illegible]	
11	New York	18½	S	S side S walk	North Carolina	9½	W	E side E walk	2	[illegible]	-	THd	[illegible]	
12	North Carolina	19½	W	E side E walk	New York	10½	N	S side S walk	2	Eddy	-	THd	[illegible]	
13	Colorado	22½	S	N side N walk	Florida	6½	W	E side E walk	4	[illegible]	L	11	[illegible]	
14	Colorado	11	N	S side S walk	Florida	6½	W	W side W walk	4	[illegible]	L	12	[illegible]	
15	New York	16	S	N R	Florida	14	W	W R	6	[illegible]	L	10½	[illegible]	Bal Tap
16	New York	10½	S	S side S walk	Florida	9½	W	E side E walk	2	[illegible]	-	THd	[illegible]	
17	Virginia	2½	S	N side N walk	Florida	20½	W	W side W walk	6	[illegible]	L	18	[illegible]	
18	Virginia	2	N	S side S walk	North Carolina	5½	W	[illegible]	6	[illegible]	L	10½	[illegible]	
19	Tennessee	7½	E	W side W walk	New York	6½	N	N side N curb	6	[illegible]	L	22	[illegible]	
20	Tennessee	7½	E	W side W walk	New York	6	N	N side N walk	6	[illegible]	L	10½	[illegible]	
21	New York	2	S	N side N walk	Tennessee	9½	E	E side W curb	6	[illegible]	L	20	[illegible]	
22	New York	6¾	S	N side N walk	Tennessee	10½	W	W side E curb	6	[illegible]	L	22	[illegible]	
23	Tennessee	2	E	W R	Pennsylvania	6	N	N R	6	Lud.	L	22	[illegible]	in Vault
24	Pennsylvania	7	S	N R	Tennessee	8	E	W R	6	Lud.	L	22	[illegible]	
25	Tennessee	6	W	W R	Pennsylvania	7	S	N R	6	Lud.	L	22	[illegible]	
26	Virginia	1½	N	N curb	Drive to [illegible] Virginia	6	W	¢	6	Eddy	L	20	[illegible]	
27	Pennsylvania	10	N	S R	Tennessee	12	E	W R	6	Eddy	L	20	[illegible]	
28	New York	7	S	N side N walk	Massachusetts	28½	W	W side W walk	6	Vogt	L	18	[illegible]	
29	Massachusetts	13	E	W side W walk	New York	26	N	N side N walk	6	Vogt	L	18	[illegible]	
30	New York	20	N	S curb of park	Massachusetts	8½	E	W curb park	6	[illegible]	L	19½	[illegible]	
31	Hawaii	9	E	W curb	Maryland	17	N	S curb	4	Ken	L	12	[illegible]	
32	Private Drive	40	E	W curb Hawaii	Maryland	4	S	S curb	4	[illegible]	L	12	[illegible]	
33	Virginia	4½	S	S curb	Hawaii	32	E	E curb	4	[illegible]	L	12	[illegible]	
34	Pennsylvania	4½	S	S side N walk	North Carolina	5	E	E edge E walk	6	[illegible]	L	10½	[illegible]	
35	Pennsylvania	12	S	N R	North Carolina	13	W	W R	6	[illegible]	L	10½	[illegible]	
36	Pennsylvania	12	S	N R	North Carolina	22	W	W R	6	[illegible]	L	21	[illegible]	
37	Maryland	32	N	S side S walk	B.&O. RR	29	E	E rail	4	[illegible]	L	10	[illegible]	
38	Pennsylvania	9	N	S R	Tennessee	200	E	E R	6	[illegible]	L	10½	[illegible]	15' W of Hydrant
39	New York	22	S	N R	North Carolina	11	E	E R	6	[illegible]	L	10½	[illegible]	
40	New York	22	S	N R	North Carolina	[illegible]	E	E R	6	[illegible]	L	10½	[illegible]	2' N of Hydrant
41	Kentucky	12	E	W R	New Jersey	16	S	S R	8	A.R.C.	R	27	[illegible]	Note-Opens Right
42	Pennsylvania	12	S	N R	Florida	47	W	W R	6	[illegible]	L	10½	[illegible]	
43	Pennsylvania	4½	S	S edge N walk	Florida	11	E	E edge E walk	6	[illegible]	L	10½	[illegible]	
44	Pennsylvania	2½	N	N edge N walk	Florida	20	E	E edge E walk	6	[illegible]	L	10½	[illegible]	
45	Virginia	20	S	S edge N walk	Hawaii	9	E	[illegible]	6	[illegible]	L	10½	[illegible]	
46	Canada	7	S	N R	Vermont	12	W	W R	6	Cha	L	18	[illegible]	
47	Canada	7½	S	N R	Texas	7½	W	W R	6	Cha	L	18	[illegible]	
48	Indiana	3½	E	W edge W walk	Maryland	6½	N	N edge N walk	20	[illegible]	L	42	1921	
49	Maryland	10½	S	S edge N walk	Indiana	1½	E	W edge W walk	12	[illegible]	L	30	1921	By Pass
50	Maryland	12½	S	N edge N walk	Indiana	[illegible]	E	E side E walk	20	[illegible]	L	42	1921	
51	Indiana	21½	E	W edge W walk	Maryland	10½	S	S edge S walk	6	[illegible]	L	12	[illegible]	
52	Indiana	12½	E	W R	Pennsylvania	[illegible]	S	S R	6	[illegible]	L	14	[illegible]	By Pass

Note: Four additional valve lists are necessary to show all valves on Plat 24 I.

Figure 16-11 -- Valve List

to property line or street centre line or curb, intersecting street with reference measurements to property lines or centre line or curb, size and make of valve, direction of operation.

Where an intersection has complicated detail a large scale map supplement may be drafted and properly referenced and inserted into this record.

Index for "Valve Map and List Record" should follow the format used for "Section Maps".

This type of record gives the operating staff all the essential valve information and also shows how the mains are tied in. Its thickness is but a fraction of an intersection book.

Here again, corrections and additions should be shown in contrasting colours on copies of these records.

Figures 16-10 and 16-11 show a typical layout for such a record. These examples are copies from the A.W.W.A. M8 Water Distribution Training Manual.

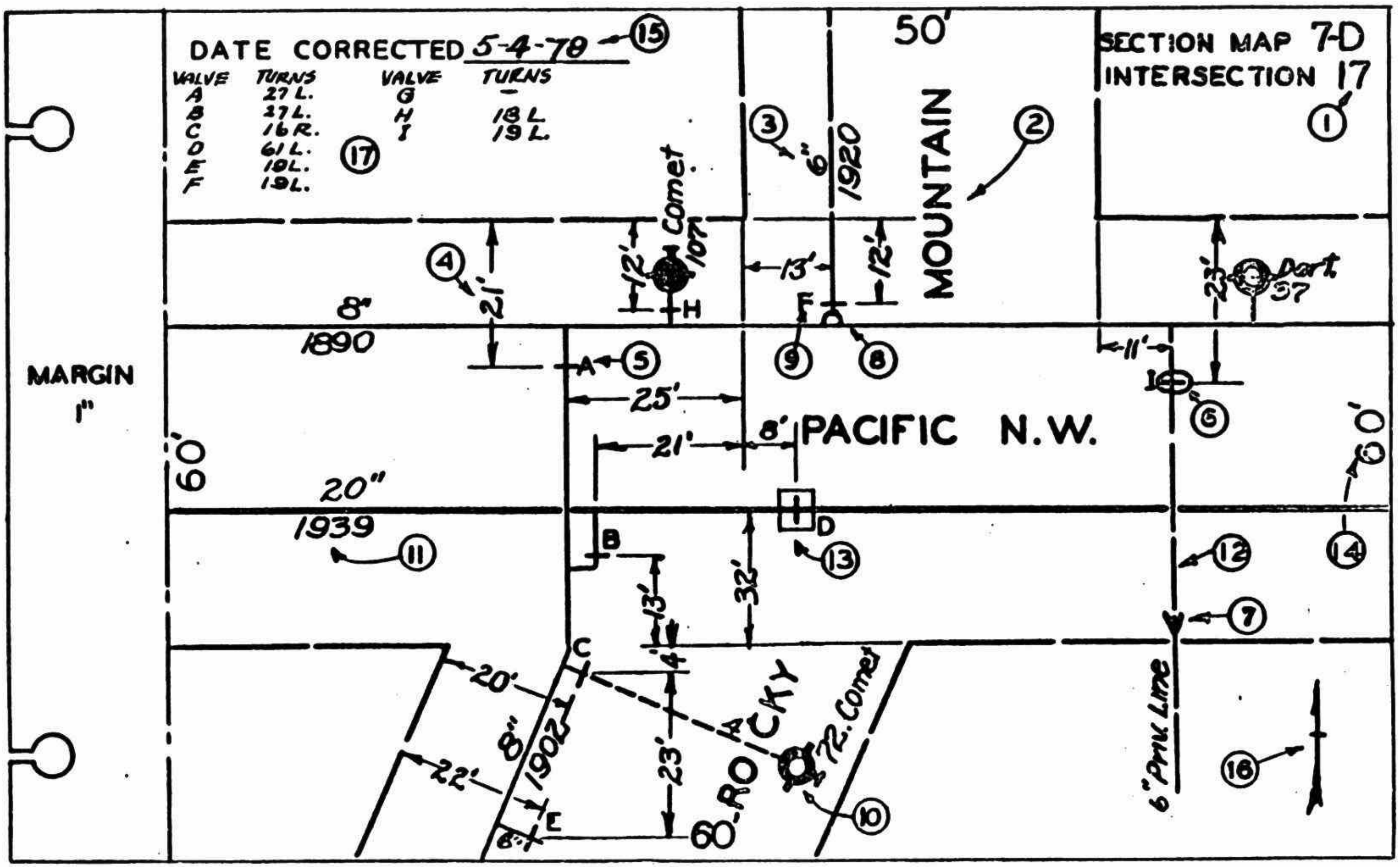


Figure 16-12 - Valve Intersection Plat

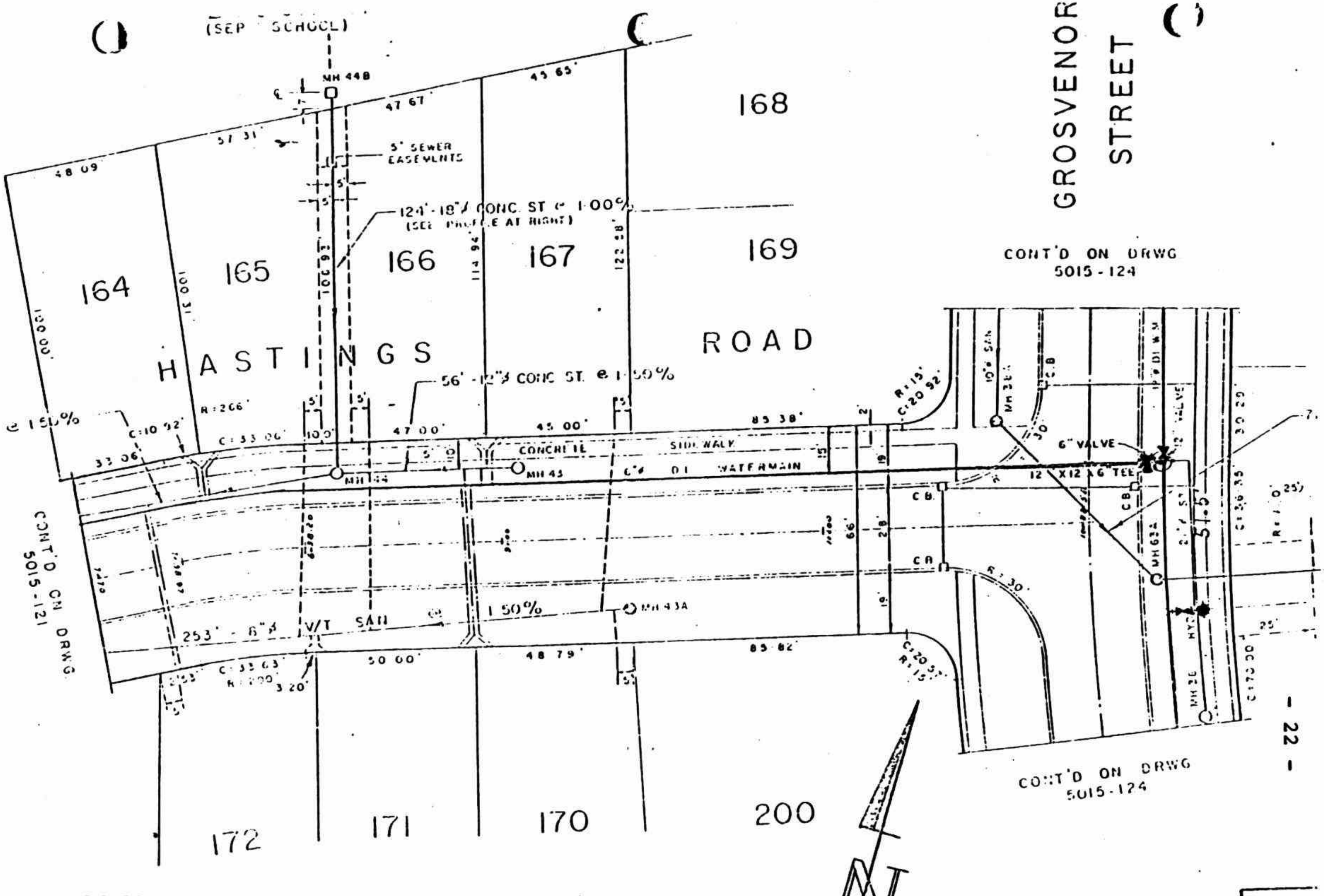


Figure 16-13 REGION OF HALTON
SAMPLE OF INTERSECTION SHEET
OAKVILLE WATER SYSTEM

NOTE: This is a photocopy of "as built" engineering drawing.

"Intersection Sheet" Record

This system requires the drawing of intersection maps on which mains, valve, hydrants, etc. are shown. These maps are at such a scale that dimensions to permanent reference points, preferably property lines or street lines, can be given. The scale should be either 1:200 (1" = 20 ft.) or 1:400 (1" = 30 ft.). Valves between intersections cannot be shown to scale but dimensions from intersecting streets should be given to locate such out of scale items.

Indexing such a record can follow a number of methods. One method is to relate the intersection sheet with the sectional map. Another is to list the intersections alphabetically suffixed with a number. Use the first letter of the name for the East-West Street then follow with a number. Of course, a cross referenced index, should be included with each intersection book.

Use a standard letter sized sheet for intersection sheets. Enough detail for an intersection can be compiled on a sheet this size. Smaller sheets will tend to restrict the amount of legible information.

The big disadvantage of such a record is that it quickly becomes too bulky. The operating staff would tend to find the record awkward to handle in the field.

Figures 16-12 and 16-13 show sample intersection sheets. To avoid the time consuming chore of drafting each new intersection sheet, photocopying techniques may be employed. That is, photocopy the intersection off the revised "as built" engineering drawing of the new works. Thereafter embellish the photocopy with pertinent data required for the Intersection Sheet Record.

SUPPLEMENTED MAPPED RECORDS

Other maps are maintained in a water works system. These maps are basically for planning purposes. They include:-

1. Arterial Map - show primary Distribution Mains

2. Valve Closure Map - Show Valving Weaknesses

3. Leak Survey District Map

4. Water Gradient or Pressure Contour Map

5. Leak Frequency Map.

CARD RECORDS

Certain distribution system records are difficult to put in a mapped form; these are usually kept on cards. These are records of individual valves, hydrants, services, meters, etc. where it is desirable to keep both location, description and historical data for each unit.

This topic will not describe the cards since the sample cards at Appendix A show clearly the data which should be provided for. Space is allowed on each card for a short statement of the maintenance performed.

A natural inclination will be to show too little original information on these cards. The original time required to list complete data will be only a minute or so longer than it takes to list incomplte data, whereas a few years later it will take hours to obtain data omitted on just a single item. Therefore, each card should have places provided for all the pertinent data. However, certain of the items shown on the cards may be omitted in specific cases. Each user has specific needs. Design the data list to suit the operation.

Instant photographs - eg. "Polaroid Camera" are beneficial to creating records of intersection sheets, special construction techniques, before and after scenes of construction sites, etc.

These copying techniques have caused a change in the methods and materials used for the original records, eg. using bond paper and pencil lines, in lieu of tracing cloth or mylar and ink lines.

Remember, time is money. Where you can assist in producing fast and accurate records, you will aid the efficient operation of your Utility.

MAINTENANCE RECORDS

While a water utility can operate without keeping many records of maintenance work performed, it is usually necessary for the superintendent or manager to report the amount of maintenance work performed to justify the expenditures which are under his supervision.

The sample sheets included in Appendix A are presented for several of the maintenance operations. Where historical records are kept of valves, hydrants, services, etc., these operation reports should be transcribed or attached to the individual historical cards before the reports are filed.

REPRODUCTION OF ORIGINAL MAPS AND RECORDS

In the last decade, new reproducing techniques have been developed and improved. A basic philosophy in drafting is "never draw the same line twice", hence the following.

Records can be microfilmed and from this film any size copy of the record can be produced for a specific need. For security reasons, records should be microfilmed. Store the film in a bank vault or fire-proof chamber. Halton Region microfilmed all their plans and records at a cost of 40¢ per frame. The reduced size drawings enable the operating staff to be provided with manageable size field copies.

Electrostatic copiers, such as the "Xerox" or "IBM" copier should be employed to make fast and inexpensive copies of records.

White printing machines have been improved to give high quality prints at fast printing speeds.

APPENDIX A

CARD RECORDS

XYZ WATERWORKS

VALVE RECORD

NO. 24-I-15

LOCATION: NEW YORK W. of FLORIDA 16 FT. S OF N PROP. LINE OF NEW YORK
AND 14 FT. W. OF W. PROP. LINE OF FLORIDA
SIZE: 6" MAKE: XXX TYPE: GATE GEARING: NO BY-PASS NO
OPENS: LEFT TURNS TO OPERATE: 19½ SET IN: AA BUFFALO BOX DEPTH TO NUT 32"
REMARKS: TAPPING VALVE ON 6" x 6" SLEEVE

(SKETCH ON BACK IF NECESSARY)

MAINTENANCE & INSPECTION RECORD

DATE	WORK DONE	O.K.	BY	DATE	WORK DONE	O.K.	BY

(5"X 8" CARD)

Valve Card Record

XYZ WATERWORKS

REPORT EVERY OPERATION

3" X 5" SHEET

VALVE OPERATION REPORT

VALVE PLAT 24-I VALVE NO. 15 DATE 8-26-78
PRINCIPAL ST. NEW YORK 12 FT. S. OF N. R.
INTERSECT. ST. FLORIDA 19 FT. W. OF W. Curb.
SIZE 6" MAKE XXXX OPENS L. TURNS 19½ DEPTH 32"
VALVE RECORD: INCORRECT ✓ CORRECT REMARKS: Box was off center - Realigned - Now O.K.
OFFICE CHECK 8-29-68 OPER. BY John Smith

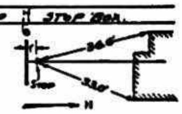
Valve Operation Report

XYZ WATERWORKS

CONSUMER'S SERVICE RECORD

TAP NO. 35631
WORK ORDER NO. S-1492

ADDRESS 7273 NEBRASKA ACCT. NO. 14-858 DATE INSTALLED 9-20-67
LOCATION OF TAP N SIDE OF 6" MAIN 156 FT. E OF E PL. OF TEXAS AVE
MAIN 1' STOP BOX 6' PROP. LINE 25' BLDG. TOTAL LENGTH 32' FT.
SIZE CORP. 5/8" ; SIZE SERVICE 1" ; MATERIAL LEAD
CURB COCK 1" ; STYLE INVERTED ROUNDWAY ; SET IN LOCK TOP STOP BOX.
REMARKS REPLACES OLD SERVICE.
OLD TAP #10091 DESTROYED



MAINTENANCE RECORD

DATE	FOREMAN	WORK PERFORMED

(5"X 8" CARD)

Service Card Record

XYZ WATERWORKS

HYDRANT RECORD

NO. 181

LOCATION N.W. COR. CANADA AND TEXAS — WORK ORDER NO. 1761
DATE SET 4-18-29 MAKE XXXX — OUTLETS 2 2½" : 1 4½" — DEPTH OF BURY 6½'
SIZE OF: BARREL 6" VALVE OPENING 4" HUB OPENING 6" — HYDRANT OPENS LEFT
BRANCH SIZE 6" LENGTH 18' CONNECTS TO 8" MAIN ON TEXAS WITH TAPPING SLEEVE
BRANCH VALVE: MAKE XXX OPENS LEFT TURNS 12 LOCATED 4 FT. E OF HYDRANT
ELEVATION 116' STATIC PRESS: NORMAL 70# PEAK HR. 66# RESID. PRESS. ONE 2½ OPEN 34# CLASS A
REMARKS: GUARD POSTS SET TO PROTECT HYDRANT

MAINTENANCE & INSPECTION RECORD

DATE	WORK DONE	O.K.	BY	DATE	WORK DONE	O.K.	BY
					(3"x 6" CARD)		

Hydrant Card Record

XYZ WATER WORKS.
EXTENSION ORDER

On Maple Avenue Street
In FOREST GLEN Subdivision
City XYZ Sch. Dist. FOREST
Sewer Dist. FOREST Plat Sheet No. 17-M

PIPE LAID

Laid 211 ft. of 6" C.I. pipe
on MAPLE AVE.
from a point 13' S. OF S. P.L. OF NORTH DRIVE.
to a point 224' S. OF S. P.L. OF NORTH DRIVE.
Main lies 9 ft. E. OF W. P.L. OF MAPLE AVE.

TYPE OF EXCAVATION

Concrete — Sq. Ft. Tarvia 76 Sq. Ft.
Tunnels 19 Ft. Rock 100 Cu. Ft.

RETIREMENT

Retired 96 ft. of 2" GALV. Pipe
on MAPLE AVE.
from POINT 13' S. OF S. P.L. OF NORTH DRIVE.
to POINT 109' S. OF S. P.L. OF NORTH DRIVE.
Original Installation Date MARCH, 1916.

	Hour	Date
Job Started	10 AM.	8-2-69
Job Finished	4 P.M.	8-3-69

Sterilized 8-3-69 By John Doe
By John Doe Foreman
Checked By J.McD. Engineer

TERMS OF EXTENSION

Job No. P-715 Work Order No. 2871

DEPARTMENT EXTENSION:
Purpose: —

PROMOTER'S EXTENSION:
A. B. White contracted for 204 ft. of 6" pipe
on Maple Avenue from North Dr. South
to C/L Lot 6 Bl. 2 by contract dated 6-20- 19[illegible]
at $1.35 per ft. $275.40 total.
Amt. paid $100. Date 6-20 19 69. Balance $175.40, paid 7-15, 19 69

MATERIAL USED ON MAIN

	Amt.	Size	Class	Lining	Joint	Make
Pipe	207'	6"	150	CEM.	SULPHUR	[illegible]
Valves Boxes and Stakes			Make	Ident. Marks	Turns To Open	
	1	6"	XXX	1938	19-L	
	1	A	VALVE BOX			
	1	2"	XX	1B. FLUSH VALVE		
	1	143	VALVE BOX			
Fittings			Kind	Descrip.		
	2	6"	22½°	4-WAY	B.S. BENDS	
	1	6"x2"		4-WAY	TAPPED PLUG	
	1	2"	45°	GALV.	ST. ELL	
	1	2"x10"		GALV.	NIPPLE	
	1	2"x4'		GALV.	RISER PIPE	
Other Materials	60#	SULPHUR COMPOUND.				
	47½'	½" SQ. YARN.				
	2½'	¾" " "				
	1 GAL.	KEROSENE				
	½ TON	2" MACADAM				

MATERIAL USED TRANSFERRING SERVICES

Amt.	Size	Description

Mileage Rec. 8-31-39 By G.A.
City Map 8/15/39 By G.A.
Plat Sheet 9-4-39 By C.C.
Comp. Map 9-30-39 By C.C.
Valve Rec. 8-8-39 G.A.
Credited S. H. 8-31-39 By [illegible]

ORDER TO LAY PIPE

To John Doe Foreman Date July 16 19 69

You are hereby authorized to lay 204 ft. of 6" c. i. pipe on the west side of Maple Avenue from present dead end (12' s. of south property line of North Dr.) extending southwardly.

Replace 92 ft. of 2" Galv. Steel

XXX Do not salvage pipe

(SKETCH ON REVERSE SIDE) Signed R. B. Roe

Main Extension Order and Report

(5" X 8" SHEET)

HYDRANT MAINTENANCE REPORT

XYZ WATER WORKS ______ HYDRANT NO. 191

LOCATION NEW YORK W. of FLORIDA

CAPS: MISSING 1-2½" REPLACED YES GREASED YES

CHAINS: MISSING 1-2½ REPLACED YES FREED OTHERS

PAINT: O.K. NO REPAINTED CLASS A COLORS

OPER. NUT: O.K. ✓ GREASED YES REPLACED -

NOZZLES: O.K. - CAULKED 1-2½" REPLACED -

VALVE & SEAT: O.K. ✓ REPLACED -

PACKING: O.K. - TIGHTENED YES REPLACED -

DRAINAGE: O.K. NO CORRECTED BLEW OUT WITH PRESSURE

FLUSHED 25 MINUTES 1-2½" NOZZLE OPEN

PRESSURE: STATIC 69# RESIDUAL 36# FLOW 1010 G.P.M.

BRANCH VALVE: CONDITION O.K. BOX COVERED RAISED 3".

ANY OTHER DEFECTS: STEM APPEARS BENT.

STEM REPLACED -

INSPECTED 9-8-68 BY Jno. Smith

DEFECTS CORRECTED 9-11-68 BY Jim Jones

Hydrant Maintenance Report

(8½ x 11 SHEET)

FIRE HYDRANT INSPECTION REPORT

XYZ WATER WORKS

HYD. NO.	LOCATION	MAKE	CLASS	PRESSURES [illegible]	[illegible]	RESID.	PITOT	FLOW G.P.M.	MINUTES FLUSHED	WATER USED GALS.	[illegible]	DRAIN	[illegible] VALVE	REMARKS OR REPAIRS
101	CANADA & TEXAS	XXX	A	4½	80	5		[illegible]	8	[illegible]	Yes	O.K.	O.K.	
207	NEBRASKA & TEXAS	XXX	A	4½	86	16		[illegible]	4	[illegible]	"	O.K.	O.K.	
98	CALIFORNIA & TEXAS	XX	ⓓ	4½	93	-	4	[illegible]	9	[illegible]	"	O.K.	O.K.	[illegible]
542	CALIFORNIA & TEXAS	XXX	B	4½	77	-	3	[illegible]	15	[illegible]	"	[illegible]	O.K.	
711	CANADA S. OF TEXAS	X	B	4½	88	3		[illegible]	22	[illegible]	"	O.K.	O.K.	
119	MICHIGAN N. OF FLORIDA	XX	A	2½	84	31		[illegible]	40	[illegible]	"	O.K.	?	[illegible]
602	OHIO S. OF GEORGIA	XXX	C	2½	68	9		[illegible]	10	[illegible]	"	O.K.	O.K.	[illegible] operating out.
										[illegible]				

FLUSH HYDRANTS IN ORDER LISTED. REPORT REPAIRS ON HYDRANT MAINT. TICKET
PAINT TOPS & NOZZLE CAPS: CLASS A - GREEN; CLASS B - ORANGE; CLASS C - RED

DATE 4-27-39 BY [illegible]

Routine Hydrant Inspection Report

Recorded {On Plat Sheet 7-3-39 BB. / On Comp. Map 7-8-39 B.B.

XYZ WATER WORKS
FIRE HYDRANT SET ORDER

LOCATION

On N.S. of Cherry Rd.
about 300 ft. W. of Apple Drive

XYZ CITY (City) BROWN
Plat Sheet No. 19-S

REPORT

Set 6" inch SPIGOT END Fire Hydrant
299 ft. W. of W. R. of APPLE DR.
6.5 ft. S. of N. R. of CHERRY RD.
tied into 6 inch line on CHERRY RD
Hydrant shutoff valve is:
299 ft. W. of W. P. L. of APPLE DR.
8.5 ft. S. of N. P. L. of CHERRY RD
2.0 ft. S. of hydrant.

	Date	Hour
Job started	6-27-39	8:00 AM.
Job finished	6-27-39	3:30 P.M.

By John Doe (Foreman)
Initial Pressure 79#
Residual Pressure 21# Checked by J. McD. (Supervisor)
Pito Pressure
Flow 2500 G. P. M.

Hydrant was ordered set by XYZ CITY
under Ordinance #3197
Date 6-21- 1939
Hydrant No. 981
Account No. 310-5
Office Ticket No. 19763

Job No. P-435-G Work Order 2636

MATERIAL USED

Hydrant: Make and size 6" XXX
Number and diam. of outlets 1-4½"; 2-2½"
Length 4' BURY

	Amt.	Size	Description
Pipe	4'	6"	BELL PIPE, CEM. LINED.
Valves Boxes and Stakes	1	6"	XXX VALVE 1938
	1	A	VALVE BOX
Fittings	1	6"	TEE B33
	1	6"	SOLID SLEEVE
Other Materials	60#		LEAD
	7'		½" YARN
	7'		3/8" "

Credited Store House: Date 6-29- 1939. By H.J.R.

ORDER TO FOREMAN

To J. Doe, Foreman:
You are hereby authorized to set 6 inch Fire Hydrant on the N.Side of Cherry Rd. near P.D.Q. R.R. RIGHT OF WAY
in XYZ CITY

Signed R. B. Roe.
Date June 22, 1939

Hydrant Order and Report

A-5

(5" X 8" SHEET)

VALVE MAINTENANCE REPORT

XYZ WATER WORKS VALVE NO. 24-I-47

LOCATION CANADA W. OF TEXAS

MEASUREMENTS: CHECKED O.K. ✓ MEASURED AS FOLLOWS:

_______ FT. _____ OF _____ P.L. OF _______

_______ FT. _____ OF _____ P.L. OF _______

VALVE: TURNS LEFT TO OPEN. NO OF TURNS 19

FOUND PARTLY CLOSED OR 7 TURNS CLOSED ____

PACKING: O.K. – TIGHTENED – REPLACED YES

STEM: O.K. ✓ BENT OR BROKEN – REPLACED –

NUT: O.K. – MISSING YES REPLACED YES

GEARS: CONDITION NONE GREASED –

BOX ✓ OR VAULT ____ O.K. ____ REPLACED ____

BURIED ______ IN. PROTRUDING ______ IN. ____

TOO CLOSE TO STEM YES RESET YES

COVER: MISSING YES BROKEN ____ REPLACED YES

WEDGED IN ______ TARRED OR GROUTED IN ______

ANY OTHER DEFECTS NONE

INSPECTED 9-27-76 BY J. Smith

DEFECTS CORRECTED 9-27-76 BY J. Smith

A-6

(5" X 8" SHEET)

SERVICE MAINTENANCE REPORT

XYZ WATER WORKS ______ TAP NO. 35631

ADDRESS 7273 Nebraska Ave.

ACCT. NO. 14/858 DATE TROUBLE REPORTED 9-30-76

NATURE OF TROUBLE Leak at curb cock.

COMPLAINT MADE BY Mrs. S. Sidney

CLEANED SERVICE –

THAWED SERVICE –

REPAIRED LEAK IN INLET SIDE OF CURB COCK

REPLACED CORP. –

REPLACED STOP COCK –

REPLACED OR RESET STOP BOX LOWERED BOX 6"

REPLACED SERVICE ______

ANY OTHER WORK NO

SLIGHT LEAK IN WIPED JOINT —

WORK PERFORMED 10-2-76 BY Jim Ford

REPORT OF LEAK

XYZ WATER WORKS NO. 231-1976

LOCATION California - East of Texas

TIME REPORTED 9:10 P.M. (HOUR) Fri. (DAY) Sept. (MONTH) 29 (DAY) 1976 (YEAR) BY (TELEPHONE ✓ (CALL AT OFFICE (LETTER

REPORTED BY C. Jamison ADDRESS 7290 A California

REPORT RECEIVED BY Addison Sims

DISPOSITION OF REPORT Called Geo. Brown to gather crew and go to leak

— OFFICE RECORD —

REPAIR CREW REPORT RECEIVED AND FOUND SATISFACTORY Yes

INJURY OR DAMAGE INSPECTED BY A. Scott DATE 9-30-76

ESTIMATE OF EXTENT OF DAMAGE $275.00

IS SUPPLEMENTARY REPORT NECESSARY? Yes SUPP. REPORT ATTACHED Yes

SHOULD REPORT OF THIS LEAK GO TO LEGAL DEPT.? Yes

HAS REPORT BEEN MADE TO LEGAL DEPT.? Yes

— REMARKS —

(REPORT OF REPAIR CREW ON REVERSE SIDE)

Leak Report

A-8

REPORT OF LEAK BY REPAIR CREW

EXACT LOCATION OF LEAK California Ave.
40' East of Texas Ave

SIZE AND MATERIAL OF PIPE 6" C.I.

DESCRIPTION OF RUPTURE OR BREAK Transverse Crack

PROBABLE CAUSE OF RUPTURE OR BREAK Pipe resting on large boulder

QUANTITY OF WATER ESCAPING (ESTIMATED G. P. M.) 300 G.P.M.

EXACT TIME CREW REACHED SITE OF LEAK 10:05 P.M. Fri. Sept 29, 1976

" " FLOW OF WATER WAS STOPPED 10:20 " " " " "

" " WATER ON AFTER REPAIRS 7:30 A.M. Sat. Sept 30, 1976

WHERE DID WATER ESCAPE TO Went to sewer, except about 50 G.P.M. which ran into basement of store -- 7290 California

DESCRIBE DAMAGE CAUSED BY ESCAPING WATER Wet about 24 Boxes of Shoes

DESCRIBE ACTION OF EMPLOYEES TO MINIMIZE DAMAGE Moved boxes off wet floor

NAMES OF EMPLOYEES AT LEAK:	NAMES AND ADDRESSES OF OTHER WITNESSES:	
A. White	C. Jamison	7290 California
C. Gray	R. Swan	7306 Nebraska
F. Black	C. Jacobs	7270 Michigan

REMARKS Small Gasoline Pump # 2 did not operate satisfactorily. Trouble in gas feed.

(SEE OTHER SIDE FOR ADDITIONAL REMARKS)

REPORT BY [illegible] Brown

Leak Report, Reverse Side

HYDRANT RECORD

A-9

OAKVILLE P.U.C. NO. ____________

LOCATION ____________

DATE SET ____________ MAKE ____________ OUTLETS ____________ DEPTH OF BURY ____________

SIZE OF: BARREL ____________ VALVE OPENING ____________ HUB OPENING ____________ HYDRANT OPENS ____________

BRANCH SIZE ____________ LENGTH ____________ CONNECTS TO ____________ MAIN ON ____________

BRANCH VALVE: MAKE ____________ OPENS ____________ TURNS ____________ LOCATED ____________ FT. ____________ OF HYDRANTS

NORMAL STATIC PRESSURE: ____________ RESIDUAL PRESSURE: ONE 2½ PORT OPEN ____________

REMARKS: ____________

MAINTENANCE AND INSPECTION

DATE	WORK DONE	OK	BY	DATE	WORK DONE	OK	BY

FORM NO. 400.024

Oakville P.U.C.

VALVE RECORD

Inspection Ref. Sheet No.

Location Ft. Of

And Ft. Of

Size Make Type Gearing By-Pass

Opens Turns to Operate Set In Depth to Nut

Remarks

MAINTENANCE AND INSPECTION RECORD

DATE	WORK DONE	OK	BY	DATE	WORK DONE	OK	BY

FORM NO. 400.025

OAKVILLE

PUBLIC UTILITIES COMMISSION

WATER

METER INSTALLATION REPORT

No. ____________

Account No. ____________ Date ____________

Name of Customer ____________

Address ____________

Instructions ____________

INSTALLED	REMOVED
METER SIZE	METER SIZE
SERVICE SIZE	SERVICE SIZE
TYPE	TYPE
SERIAL	SERIAL
READING	READING

DOMESTIC ☐ COMMERCIAL ☐ INDUSTRIAL ☐

Work completed by ____________

400.027

16-36

VALVE MAINTENANCE REPORT

OAKVILLE P.U.C.

INTERSECTION REF. SHEET .... VALVE NO. ....

LOCATION ....

....

.... FT. .... OF .... P.L. OF ....

.... FT. .... OF .... P.L. OF ....

VALVE TURNS .... TO OPEN. NO. OF TURNS ....

FOUND .... OR .... TURNS CLOSED ....

PACKING: O.K. .... TIGHTENED .... REPLACED ....

STEM: OK .... BENT OR BROKEN .... REPLACED ....

OPERATING NUT OK .... MISSING .... REPLACED ....

GEARS: CONDITION .... GREASED ....

BOX .... OR VAULT .... OK .... REPLACED ....

BURIED .... IN" PROTRUDING .... IN"

TO CLOSE TO STEM .... RESET ....

COVER: MISSING .... BROKEN .... REPLACED

WEDGED IN .... TARRED OR GROUTED IN

ANY OTHER DEFECTS ....

DATE INSPECTED .... BY ....

DEFECTS CORRECTED ....

DATE .... BY ....

16-37

HYDRANT MAINTENANCE REPORT

OAKVILLE P.U.C. HYDRANT NO. ....

LOCATION ....

CAPS: MISSING .... REPLACED .... GREASED ....

CHAINS: MISSING .... REPLACED .... FREED ....

PAINT: OK .... REPAINTED ....

OPER. NUT OK .... GREASED .... REPLACED ....

NOZZLES: OK .... CAULKED .... REPLACED ....

VALVE & SEAT: OK .... REPLACED ....

DRAINAGE: OK .... WET .... DRAINS SEALED ....

PACKING: OK .... TIGHTENED .... REPLACED ....

FLUSHED .... MINUTES .... NOZZLE OPEN ....

PRESSURE: STATIC .... RESIDUAL ....

FLOW .... G.P.M.

BRANCH VALVE: CONDITION ....

OTHER DEFECTS ....

....

....

....

INSPECTED .... BY ....

DEFECTS CORRECTED .... BY ....

A-11

THE REGIONAL MUNICIPALITY OF HALTON
WATERMAIN EXPOSURE REPORT

DATE: ______ ~~A-12~~
W.O. No. ______
BREAK No. ______
NOTIFIED ______
OFF ______
ON ______

FIELD DATA FOR MAIN BREAK EVALUATION

STREET ______

TYPE OF MAIN: ______ SIZE ______ JOINT ______ COVER ____ FT. ____ IN.

THICKNESS AT POINT OF FAILURE ______ INCH.

NATURE OF BREAK: Circumferential ☐ Longitudinal ☐ Circumferential & Longitudinal ☐ Blowout ☐ Joint ☐

Split at Corporation ☐ Sleeve ☐ Miscellaneous ______ (describe) ☐

APPARENT CAUSE OF BREAK: Water Hammer (surge) ☐ Defective Pipe ☐ Corrosion ☐ Deterioration ☐

Improper Bedding ☐ Excessive Operating Pressure ☐ Differential Settlement ☐ Temp. Change ☐ Contractor ☐ Misc. ______ (describe) ☐

STREET SURFACE: Paved ☐ Unpaved ☐ TRAFFIC: Heavy ☐ Medium ☐ Light ☐

TYPE OF STREET SURFACE ______ SIDE OF STREET: Sunny ☐ Shady ☐

TYPE OF SOIL ______ RESISTIVITY ______ ohm/cm

ELECTROLYSIS INDICATED: Yes ☐ No ☐ CORROSION: Outside ☐ Inside ☐

CONDITIONS FOUND: Rocks ☐ Voids ☐ PROXIMITY TO OTHER UTILITIES ______

DEPTH OF FROST ______ INCH DEPTH OF SNOW ______ INCH

OFFICE DATA FOR MAIN BREAK EVALUATION

WEATHER CONDITIONS: PREVIOUS TWO WEEKS ______

SUDDEN CHANGE IN AIR TEMP? Yes ☐ No ☐ TEMP ____ °F RISE ____ °F FALL ____ °F

WATER TEMP.: SUDDEN CHANGE: Yes ☐ No ☐ TEMP ____ °F RISE ____ °F FALL ____ °F

SPEC. OF MAIN ______ CLASS OR THICKNESS ______ LAYING LENGTH ____ FT.

DATE LAID ______ OPERATING PRESSURE ______ PSI PREVIOUS BREAK REPORTED ______

INITIAL INSTALLATION DATA:

TRENCH PREPARATION: Native Material ______ (describe type) ☐ Sand Bedding ☐ Gravel Bedding ☐

BACKFILL: Native Material ☐ DESCRIBE ______ Bank Run Sand & Gravel ☐

Gravel ☐ Sand ☐ Crushed Rock ☐ OTHER ______

SETTLEMENT: Natural ☐ Water ☐ Compactors ☐ Vibrators ☐ OTHER ______ (describe)

ADDITIONAL DATA FOR LOCAL UTILITY USE

LOCATION OF BREAK ______ MAP NO. ______

REPORTED BY ______

DAMAGE TO PAVING AND/OR PRIVATE PROPERTY ______

______

REPAIRS MADE (Materials, Labor, Equipment) ______

______

REPAIR DIFFICULTIES (If Any) ______

______

INSTALLING CONTRACTOR ______

Drawing on Back ______ Foreman Sign. ______

Report Made By ______ Eng. Dept. Sign. ______

A-13

THE OAKVILLE PUBLIC UTILITIES COMMISSION

Engineering & Operations Department

WATER METER SHOP TESTS

Date________________

Size	Serial #	Incoming Tests			Outgoing Tests			Year
		Low	Int.	Full	Low	Int.	Full	

Form #:
400.041

PROJECT NO. ....

REGIONAL MUNICIPALITY OF HALTON

FIELD NOTES

A-14

WATER SERVICE
HYDRANT
VALVES ON MAINS

DATE ____________ STREET ____________________ NO. __________

OWNER ____

DATE LAID ____

LENGTH ________ MAIN TO CURB STOP __________ CURB STOP TO BASEMENT ______

MIN. DEPTH AT MAIN ____________________ CURB BOX ______________

MATERIAL ____________________ CORP. STOP __________ MAIN STOP ________

____________________________ PIPE __________ POST __________

METER INSTALLED ____________________ SERIAL No. ______________

____

REMARKS: ____

____

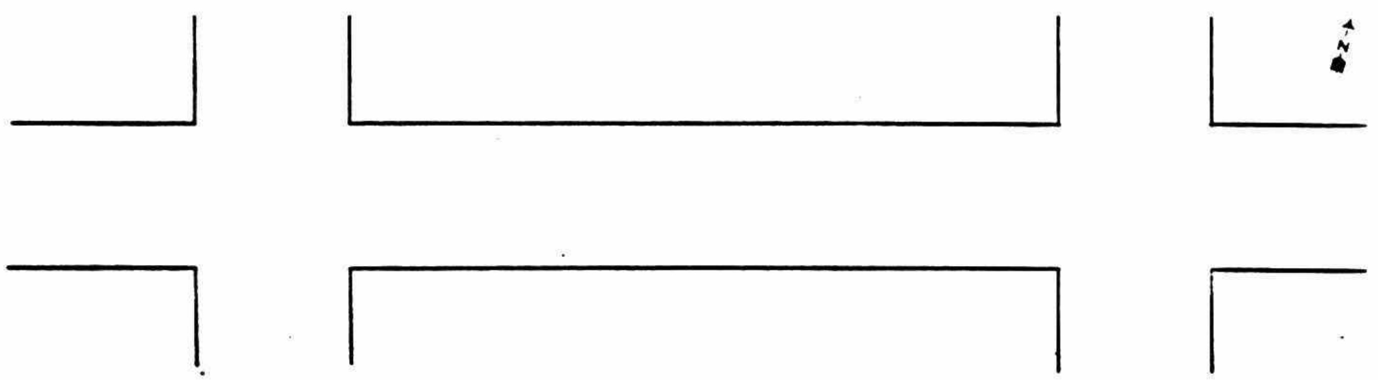
____

____

____

____

____



DATE COMPLETED ______________________________ CONNECTED ______________

400 030